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WIRING
FOR
LIGHT AND POWER

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IN PREPARATION

ELECTRICAL MACHINERY
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WIRING
FOR
LIGHT AND POWER

A DETAILED AND FULLY ILLUSTRATED COMMENTARY ON THE MORE IMPORTANT PORTIONS OF THE NATIONAL ELECTRICAL CODE

BY

TERRELL CROFT

CONSULTING ELECTRICAL ENGINEER
AUTHOR OF AMERICAN ELECTRICIANS' HANDBOOK
WIRING OF FINISHED BUILDINGS, ETC.

FIRST EDITION

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PREFACE

Almost any one can install electrical wiring and apparatus so that they will work in some fashion or other. But to install them so that they will be electrically safe and mechanically secure involves the application of knowledge that has been gained accumulatively by hundreds of workers during many years of practice. Obviously, it is scarcely feasible for any one individual, unaided, to acquire from his own experience this requisite knowledge. Hence, if one is to follow the best methods in installing electrical equipment he must necessarily avail himself of the knowledge and experience obtained by his predecessors.

It is extremely fortunate, for those of us who live on this continent, that the gist of the accumulated knowledge and experience, concerning American methods of installation of electrical wiring and apparatus has been concisely incorporated in a set of rules or specifications which has been named "The National Electrical Code." Doubtless, the Code comprises the most comprehensive collection of directions for electrical wiring and installation ever compiled. It includes sections specifying installation methods for wiring and equipment for nearly all services and purposes. Its principal function is to specify wiring-and-installation methods which will minimize fire hazard—and at the same time be economically feasible. Obviously, this is a broad field to cover. Hence, the rules of the Code should necessarily be, and are in many cases, very concise. In other words, the Code is almost wholly free from explanations or elaborations.

The purpose, then, of the book "Wiring for Light and Power" is to supply explanations, elaborations and illustrations for those sections of the National Electrical Code to which it is necessary to refer most frequently. The book has incorporated in it, verbatim, the most important National-Electrical-

Code regulations. Then these regulations or rulings and their application in practical electrical construction are explained by supplementary text prepared by the author and fully illustrated.

Furthermore, in most cases, where such explanations are feasible and available, the reasons for the adoption of the Code rules are discussed by the author. Certain of the Code rules have been criticised as being unduly stringent or uncalled for, because the critic did not know why the rules were incorporated and because he was not familiar with all of the facts affecting the situation. Where the reasons for the inclusion of the rules are known, much less difficulty is encountered in their enforcement. Furthermore, the rules can be much more readily remembered and interpreted if one is familiar with the whys and wherefores.

Much labor has been expended to render the index of this book comprehensive and usable. This feature is particularly recommended to the reader's attention.

Every effort has been made to insure accuracy, the proofs having been read five different times by five different people, all of whom are more or less familiar with the Code and its requirements. However, it has been the author's experience that it is seemingly impossible to eliminate all errors from the first edition of a book as large as this. Hence, if any inaccuracies are encountered by readers it will be greatly appreciated if they will so advise the author. He will also be most grateful for all suggestions for the future enlargement or improvement of the book in any manner whatsoever.

TERRELL CROFT.

33 AMHERST AVENUE, UNIVERSITY CITY,
SAINT LOUIS, MO.,
January, 1917.

REPRINTED FROM INSIDE COVER OF THE NATIONAL ELECTRICAL CODE

"The National Electrical Code is revised every two years. The next revision will be in 1917.

"The section of the Code relating to the design and construction of appliances (Class D) is but a partial outline of specifications. Underwriters' Laboratories has complete standards for Electrical Fittings which include the provisions of this Code and in addition specifications for performance under test and in service and further details of design and construction. Copies of these standards will be furnished electrical inspection departments, manufacturing concerns, national electrical associations, societies and institutes, and copies filed with the Bureau of Standards, Department of Commerce, Washington, to which Bureau may be referred questions as to the correctness of the Laboratories' tests.

"'The List of Electrical Fittings' published semi-annually by Underwriters' Laboratories, contains a list of electrical fittings which have been examined and tested and found to comply with these standards. Copies of these lists may be obtained from local inspection departments or from the offices of the Laboratories, in the principal cities. All appliances should be submitted to Underwriters' Laboratories, 207 East Ohio Street, Chicago, or 135 William Street, New York, before being introduced for use."

ACKNOWLEDGMENTS

The author desires to acknowledge the assistance which has been rendered in the preparation of this book by a number of concerns and individuals. The editors of trade papers—*Electrical Review and Western Electrician, The National Electrical Contractor, Electrical World, Power, Everyday Mechanics, Southern Engineer, Electrical Engineering, Fire Protection,* and *Electrical News*—have granted permission for the reproduction in this book of material which originally appeared, as articles by the author, in their publications.

The page proofs were kindly read by:—Jas. H. Fenton, Electrical Engineer of the St. Louis Fire Prevention Bureau and by George B. Heath and Ralf Toensfeldt of the St. Louis Department of Public Utilities. These gentlemen called attention to some ambiguities and errors and suggested changes and additions which were—insofar as was feasible—incorporated. A number of the questions on the Code (which follow each section) were prepared by L. W. Helmreich of the David Ranken, Jr. School of Mechanical Trades, St. Louis. Charles H. Trapp has assisted the author throughout the preparation of the book and recommended many of the features and improvements.

The Westinghouse, General Electric, Crouse-Hinds, Wagner and other companies furnished data and copy and photographs for illustrations. Considerable text material is based on the explanatory notes appearing in the Factory Mutual Wiring Rules. Other acknowledgments are made throughout the book. If any have been omitted it has been through oversight and if brought to the author's attention they will be incorporated in the next edition.

PREFACE TO THE NATIONAL ELECTRIC CODE

"The National Electrical Code was originally drawn in 1897 as the result of the united efforts of the various Insurance, Electrical, Architectural and allied interests, which, through the National Conference on Standard Electrical Rules, composed of delegates from various National Associations, unanimously voted to recommend it to their respective associations for approval or adoption; and is here presented by the National Board of Fire Underwriters with the various amendments and additions which have been made since that time by them.

"The National Conference has disbanded, the work of the Underwriters' National Electric Association and of the National Conference having been taken over by the National Fire Protection Association.

"The following associations, formerly members of the National Conference, are represented on the Electrical Committee of the National Fire Protection Association:"—

American Electric Railway Association.
American Institute of Electrical Engineers.
Associated Factory Mutual Fire Insurance Co's.
National Association of Electrical Inspectors.
National Board of Fire Underwriters.
National Electric Light Association.
National Electrical Contractors Association.

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WIRING FOR LIGHT AND POWER

GENERAL SUGGESTIONS

¶*I*. The following general suggestions as well as the fine print notes in the rules are simply suggestions and explanations and are in no case to be considered by the inspection department as mandatory.

¶*II*. In all electric work, conductors, however well insulated, should always be treated as bare, to the end that under no conditions, existing or likely to exist, can a ground or short circuit occur, and so that all leakage from conductor to conductor, or between conductor and ground, may be reduced to the minimum.

¶*III*. In all wiring special attention should be paid to the mechanical execution of the work. Careful and neat running, connecting, soldering taping of conductors, and securing and attaching of fittings, are specially conducive to security and efficiency, and are strongly advised.

¶*IV*. In laying out an installation, except for constant-current systems, every reasonable effort should be made to secure distribution centers located in easily accessible places, at which points the cut-outs and switches controlling the several branch circuits can be grouped for convenience and safety of operation. The load should be divided as evenly as possible among the branches, and all complicated and unnecessary wiring avoided.

¶*V*. The use of wire-ways for rendering concealed wiring permanently accessible is most heartily endorsed and recommended; and this method of accessible concealed construction is advised for general use.

¶*VI*. Architects are urged, when drawing plans and specifications, to make provision for the channeling and pocketing of buildings for electric light or power wires, and also for telephone, district messenger and other signaling system wiring.

IMPORTANT NOTICE

The fine print matter in the following pages recites verbatim the more important portions of the 1915 National Electrical Code as recommended by the National Fire Protection Association. The matter in the large type comprises the com-

ments and explanations of the Code material by the author of the book.

The *Code* has of itself no statutory or legal force but merely comprises the rules and requirements of the National Board of Fire Underwriters. However, certain cities and municipalities in the United States have passed ordinances providing that all electrical wiring and installations in such cities shall be in accordance with the *Code*, which gives it a legal status in these cities. Moreover, other cities (see partial list below) have legalized requirements of their own, which are, usually, based on the *Code* requirements. Where local requirements are authorized by ordinance they, of course, take precedence over the *Code* rules.

Hence, the reader should ascertain whether or not the legalized Wiring Rules (if there are any such) in his city conflict with those of the *Code*. If they do, he should note, with suitable memorandums in this book, the conflictions under the Rules where the disagreements occur, and then be governed accordingly.

Among the states which have statutes relating to the installation of wiring are:—District of Columbia, Maryland, Louisiana, Tennessee, Ohio and Minnesota.

Among the cities which have passed wiring inspection ordinances or which have legalized Wiring Codes of their own (which are in almost every case more stringent than the *National Code* rules) are:—New York; Chicago; St. Louis; Denver; Portland, Ore.; Memphis, Tenn.; Macon, Ga.; Kansas City, Mo.; Jamestown, N. Y.; Newark, N. J.; Camden, N. J.; Sioux City, Iowa; San Diego, Cal.; Little Rock, Ark.; Hot Springs, Ark.; San Francisco, Cal.; Gary, Ind.; Atlanta, Ga.; Chattanooga, Tenn.; New Haven, Conn.; Madison, Wis.; Wilkes-Barre, Pa.; Moline, Ill.; Rock Island, Ill.; Peoria, Ill.; Detroit, Mich.; Louisville, Ky.; and Akron, Ohio.

WIRING FOR LIGHT AND POWER

CLASS A

(Rules 1 to 11 inclusive)

GENERATORS, MOTORS, SWITCHBOARDS, ETC.

Includes Electrical Equipment of Central Stations, Dynamo, Motor and Storage-Battery Rooms, Transformer Sub-stations, Etc.

1. GENERATORS.

1*a*. ¶*I*. GENERATORS. Must be located in a dry place.

Generators should always be installed in cool dry locations. The insulating materials used in nearly all electrical machines are usually absorbent to a certain extent and if the surrounding air contains moisture it is likely to permeate these insulating substances. When insulating materials absorb moisture, their insulating properties, that is, their resistances, are decreased. In some cases this decrease may be so great that excessive currents will be forced through the insulation, creating a "ground" or a "short-circuit." Such troubles may cause fire. Steam- or acid-laden vapors are particularly injurious to insulation.

Generators should be dried out before installation unless the installer is absolutely certain that their windings contain no moisture. Frequently the windings of machines absorb moisture in transit. They are also likely to absorb moisture in an atmosphere that is apparently dry, while being stored in a warehouse or at the location where they are to be installed. To protect against damage to the insulation all generators which may be damp should be dried out as suggested in the following paragraph before being placed in regular service.

To dry out a generator it may be operated with its armature short-circuited (Fig. 1) beyond the ammeter and with the field current so adjusted as to raise the temperature of the windings of the machine to about 70°C. (158°F.). The armature may be short-circuited by a water rheostat whereby the armature current can be decreased or increased independently of the field rheostat regulation. It will probably be necessary to operate the machine at a voltage considerably lower than normal. The current can be maintained until the coils are thoroughly dry. The temperature should not be allowed

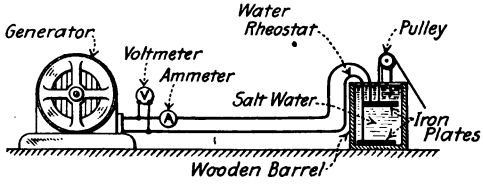


FIG. 1.—Method of drying out a generator by short-circuiting the armature leads through a water rheostat.

to decrease to that of the surrounding atmosphere because if it does the moisture will then again condense on the coils and the machine will probably become moisture saturated as before.

Caution should be observed in drying out a machine because there is always a possibility of overheating (burning out) the inner portions of the windings which cannot quickly dissipate the heat generated in them. Such inner parts may become so hot as to burn the surrounding insulation while the exposed portions, which can radiate heat readily, are still relatively cool. Frequent observations should be taken of the temperature of the hottest accessible part of the machine while it is being dried out. This can be done by binding a thermometer to this hot part as shown in Fig. 2. The bulb of the thermometer should rest in a small pad of waste or in a wad of putty lying against the part of which the temperature is to be taken. The waste pad or the putty ball is necessary to assure that the thermometer bulb will attain the temperature of the part under observation. The temperature of the

hottest accessible part of the machine should never be allowed to exceed that of boiling water, that is, 100°C. or 212°F. It may require several hours—or even days—to dry out a generator thoroughly, particularly if it is of large capacity. The field coils of large generators dry out very slowly. Inasmuch as the insulation is much more easily injured by overheating when it is damp than when dry, the electrical drying out of a machine should be effected very slowly and cautiously.

While the thermometer shown in Fig. 2, *I* and *II*, is located on the cast-iron frame of the machine so as to indicate the

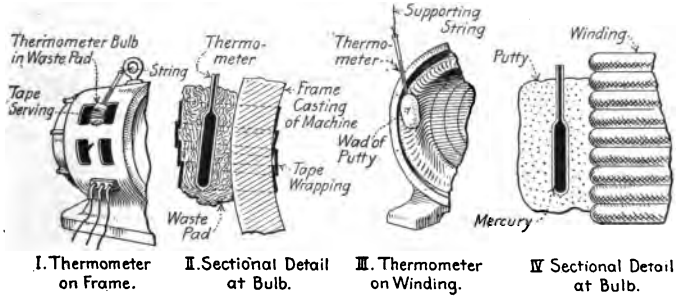


FIG. 2.—Application of thermometer in determining temperature of electrical machinery.

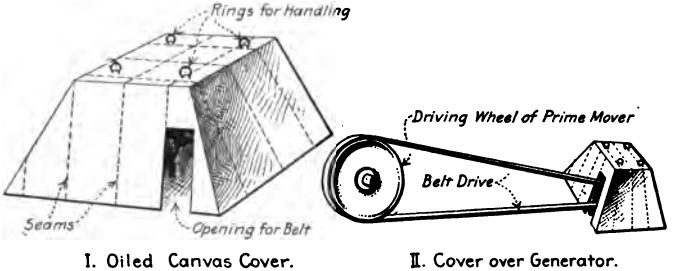
temperature thereof, the temperature of the frame casting is of itself ordinarily of no great moment. In an actual test the thermometer should be so located as to indicate the temperature of the windings (Fig. 2, *III* and *IV*) and the temperature of the iron portions of the machine that directly support the windings.

1a. NOTE.—GENERATORS. It is suggested that waterproof covers be provided which may be used in case of emergency.

Waterproof covers for generators where judiciously employed, may result in the saving of a considerable sum of money when there is a possibility of water falling on the machines because of bad roofs, or in case of fire. A waterproof cover can be made from oiled duck or waterproof canvas, about as suggested in Fig. 3. The covers should be stored near the machines which they are designed to protect and should be so folded that they

can be unfolded quickly and placed over the generators. Whenever a machine is out of service for any considerable length of time, the cover should be placed over it to prevent water from falling accidentally on the windings.

1b. ¶*I*. GENERATORS. **Must never be placed in a room where any hazardous process is carried on, nor in places where they would be exposed to inflammable gases or flyings of combustible materials.**



I. Oiled Canvas Cover. II. Cover over Generator.

FIG. 3.—Waterproof cover for electrical machines.

Generators, under certain circumstances, may constitute a fire hazard when installed where, because of local conditions, a fire can be started readily. In oil or gas storage buildings, powder factories, lint rooms, chemical laboratories and the like, inflammable gases, vapors, or flying combustibles often permeate the atmosphere. A generator should never be installed in a room where such conditions exist. The reason is that there is always a possibility (though in the case of alternating-current generators it may be a remote one) of the development of sparks at the brushes of the machine, or by a short-circuit on the lead wires. Such sparks or arcs are capable, under certain conditions, of originating an explosion or a fire.

1c. ¶*I*. GENERATORS. Must, when operating at a potential in excess of 550 volts, have their base frames permanently and effectively grounded.

The frame of a generator developing a pressure in excess of 550 volts should be grounded to provide an effective and certain path to ground for current in case the winding of the

machine becomes grounded on the frame. It is desirable to ground the frames of all generators—*Rule* 1c, ¶*II*. There must be two grounds on a circuit before current can flow to ground from the machine (this is strictly true only for direct-current machines). However, there is, in practice, practically always one ground on every electrical circuit. On a low-vol-

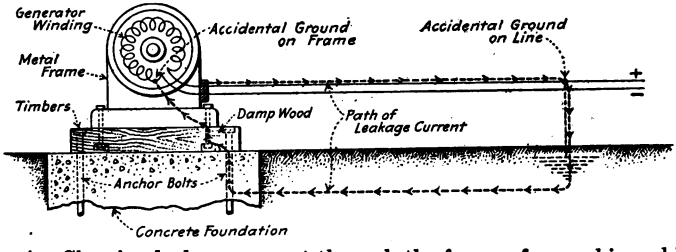


FIG. 4.—Showing leakage current through the frame of a machine which is insulated from ground.

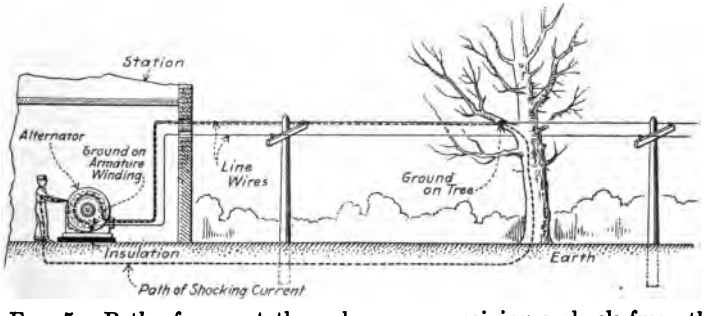


FIG. 5.—Path of current through person receiving a shock from the frame of a machine insulated from ground. (There is an accidental tree ground on the line and an accidental ground in the winding of the machine.)

tage circuit (550 volts or less) this ground may be the one associated with the ground detector outfit or it may be a permanent ground on a neutral wire as required by *Rule* 15. On a circuit operating at a pressure in excess of 550 volts the ground may be an accidental one or it may be one installed for some specific purpose. Fig. 4 shows the path of a leakage current to ground through the frame and foundation of an ungrounded machine. Fig. 5 shows how a person, standing on the earth and touching the frame of a generator which has its frame

ungrounded, would receive a shock, provided that there were a ground in the machine between one of its windings and the frame, and also another ground on the other side of the circuit at some point on the distribution system.

If an effective ground connection is not provided between the frame of the machine and the earth, and the winding becomes grounded on the frame, the path of the current to ground may be such that an arc will be produced or some part of this improvised circuit may become overheated, causing a fire (Fig. 4). Furthermore, if the frame is not thoroughly connected to ground and the winding of the machine is grounded on it, a person standing on the ground and touching any part of the frame of the machine might have a high voltage impressed on him (Fig. 5) and thereby be shocked or possibly killed. Where the generator frame is well connected to the earth, neither of the dangerous conditions suggested above can occur because any leakage currents that might develop would follow the low-resistance ground wire to earth and one could not be shocked by touching the frame of the machine because the installation of the ground wire would insure that the potential of the frame of the machine would be the same as that of the earth.

It is preferable from the operator's standpoint to ground the frames of all electrical machinery. Consider the case of the frame of a machine insulated from ground. If an electrical leak occurred in this machine between one of the windings and the frame, the operator would not ordinarily be advised of its presence and another ground might occur in the same machine between the winding and the frame, which would produce a short-circuit and possibly burn out a machine and cause a fire. If, however, the frame (not the windings) of the machine were thoroughly grounded, a leak between the frame and the winding would make itself known through an indication of the station ground detector and then it could be readily corrected before another ground could occur to make serious trouble.

If a frame is insulated it should be thoroughly insulated and if grounded, thoroughly grounded. If a frame is imperfectly

insulated, sufficient current might under certain conditions, flow through the high-resistance path (Fig. 4) constituted by the imperfect insulation outside of the machine, and cause a fire. Where the insulation is thorough, this cannot occur with only one ground on the machine. Furthermore, where the ground is thorough, it cannot occur.

The conductor for grounding a generator should never be smaller than No. 6 B. & S. gage or its equivalent and should always be of copper and of sufficient cross-sectional area to carry, without appreciable heating, the current that the fuses or the circuit-breaker protecting the machine will pass. The values shown in *Table B* of *Rule* 18 indicate conservative values for round wires. Such a ground wire may be bare. It should always be of such a size that it cannot be accidentally broken, hence never smaller than No. 6.

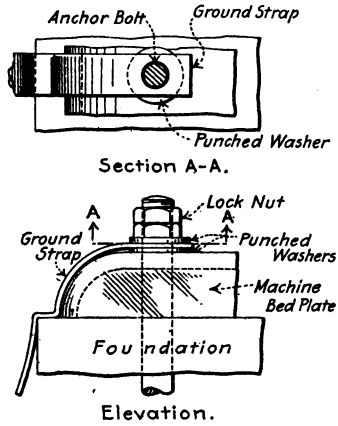


FIG. 6.—Method of connecting ground strap to machine.

Strap copper can be used for ground connections for generators as shown in Fig. 6. The general requirements for copper strap conductors as regards mechanical strength and current-carrying capacity are the same as those for a ground wire as outlined in the above paragraph. Where a large generator is being installed, a copper-strap conductor is preferable to a wire conductor because with it sufficient cross-sectional area can be secured in a form that can be readily bent to any desired contour (Fig. 6). A large, round wire cannot be conveniently formed around the foundation and into the corners and the bends which it must follow in its route to earth. Where a strap is used it can be ⅛ in. or ¼ in. or thicker and of sufficient width to provide the necessary current-carrying capacity. Such a strap can be formed without difficulty into any desired contour. At the generator end, the strap can be clamped

between two punched washers under a foundation bolt (Fig. 6). The washers should, as suggested in the following paragraph, be of copper or tinned to prevent any possibility of corrosion.

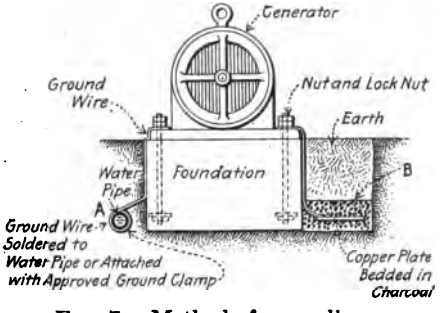


FIG. 7.—Method of grounding a generator frame.

The installation of a generator frame ground wire is made somewhat as indicated in Fig. 7. The ground wire can be connected to the generator frame as shown in Fig. 8, by clamping it between two punched washers under a foundation-bolt nut. The washers should preferably be of copper, but it is probable that iron washers would be acceptable provided that they are tinned, to prevent corrosion, and that the end of the ground wire to be clamped between them is also tinned. A locknut should be turned down over the foundation-bolt nut to prevent any possibility of loosening. The end of the ground wire should always be bent around the bolt in the same direction as that in which the nuts turn (that is, in a right-hand direction) so that any twisting action occurring when the nuts are being turned on will tend to wrap the wire around the bolt rather than to unwrap it.

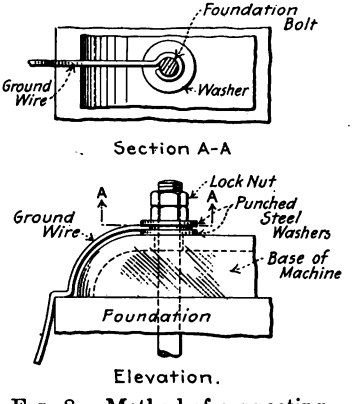


FIG. 8.—Method of connecting ground wire to machine.

The earth connection should preferably be a water pipe as shown at *A*, Fig. 7, and as described under *Rule* 15*g*, ¶*V*, but if no water pipe is available, a steam pipe is sometimes acceptable, if there is a certainty of its leading to a thorough and permanent ground. The connection to a water pipe

should always be made inside of the building, but on the street side of the water meter, where such a meter is installed.

Where no pipe is available, a ground plate as shown at *B*, Fig. 7, or a multiple-pipe ground connection may be used. Directions for preparing a ground plate are given under *Rule* 15*g*, ¶*V*, *Note*. A series of pipes driven into the earth around a generator as shown in Fig. 9 will also provide a good

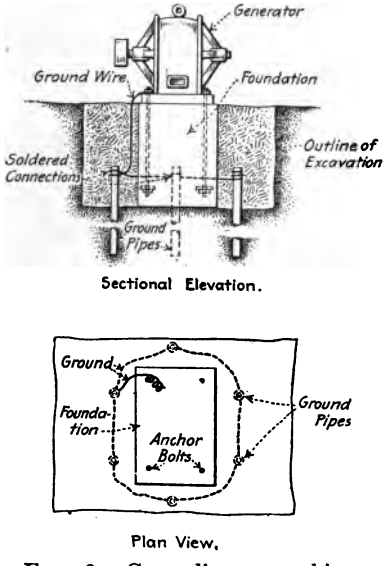


FIG. 9.—Grounding a machine frame on a multiple-pipe earth connection.

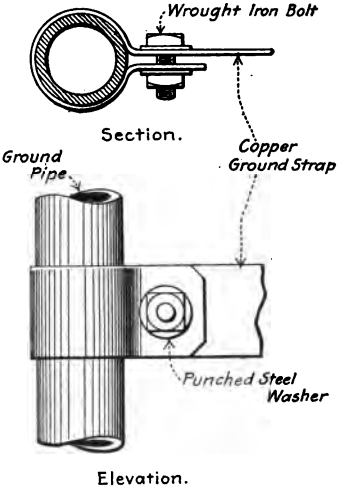
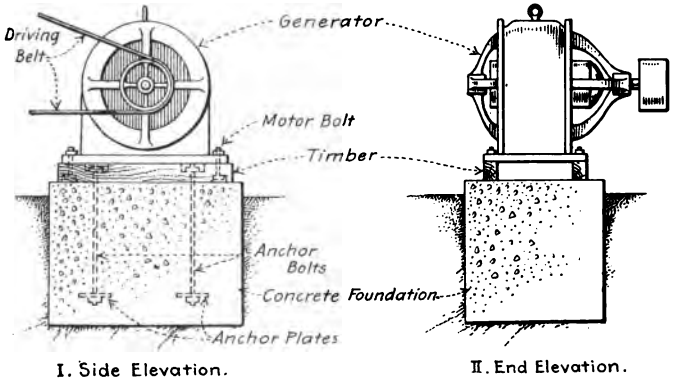


FIG. 10.—Method of connecting ground strap to pipe.

ground (see information under *Rule* 15*g*, ¶*V*, *Note*). A multiple-pipe ground connection of this sort is not as good as one provided by connecting to a pipe of an extensive water system. Other methods of making ground connections are detailed under *Rules* 5*c*, ¶*I and II* and 15*c to g*, which see.

A copper-strap ground conductor is clamped on a pipe (Fig. 10). The end of the strap in contact with the pipe and the portion of the iron pipe around which the strap is wrapped should be tinned to prevent electrolytic action.

Generators direct-connected to steam prime movers do not require further grounding, because a splendid path to ground is provided by a circuit comprising the frame of the generator and the engine and the steam and exhaust piping. The frame of a generator direct-connected to a water-wheel is usually also thoroughly grounded through the shaft between the two machines, because the water-wheel itself is usually grounded through a flume or penstock. This may not, however, always be the case, hence an auxiliary ground wire which does make a positive connection with the earth can often be advantageously installed for water-wheel machines.



I. Side Elevation. II. End Elevation.

FIG. 11.—Motor insulated on a parallel timber base.

1c. ¶*II.* GENERATORS. Must, when operating at a potential of 550 volts or less, have their base frames permanently and effectively grounded wherever feasible. Where grounding of the frame is impracticable, special permission for its omission may be given in writing, in which case the frame must be permanently and effectively insulated. Wooden base frames used for this purpose and wooden floors which are depended upon for insulation where for any reason it is necessary to omit the base frames must be kept filled to prevent absorption of moisture and must be kept clean and dry.

The insulation of generator frames from the surfaces upon which the generators stand is required if the frame of the machine cannot be grounded. In modern installations it is seldom that the frames of generators or motors are insulated

from the ground. In nearly every case it is preferable to ground the frames rather than to insulate them. Fig. 11 shows the simplest method of insulating an electrical machine from its foundation, or from the surface upon which it rests. Two insulating timbers are used under the bed plate, the bolt holes for which are countersunk as shown in Fig. 12. There should be a sufficient section of wood between the hole for the foundation bolt and that for the holding-down bolt, to provide insulation. This section in no case should be less than 1 in. in length for 220-volt machines, and a greater separation is desirable for 550-volt machines.

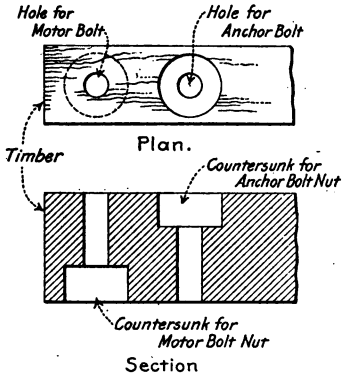


FIG. 12.—Arrangement of bolt holes in insulating timbers.

The insulating base of Fig. 11 is preferable to that of Fig. 13, because dirt and oil are apt to accumulate under the box-like cavity formed by the floor timbers of the base in Fig. 13. It may be very difficult to remove such débris. With the arrangement of Fig. 11 the dirt can be pushed out from under the machine at either end,

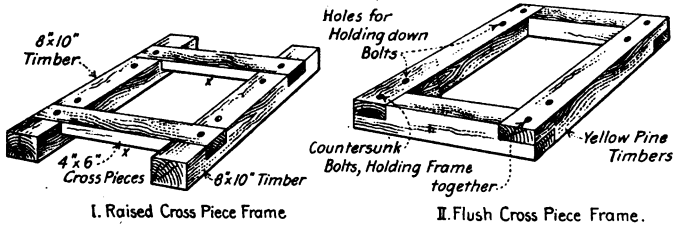


FIG. 13.—Timber frames for motor insulation.

hence the floor or the foundation top can be kept clean with little difficulty. If dirt is allowed to accumulate, it may defeat the purpose for which the timbers were placed because the timbers may become impregnated with it, which will re-

duce their insulating qualities. The construction of Fig. 13, *I*, is preferable to that of Fig. 13, *II*, because in *I* the cross pieces, *X*, extend only halfway down into the parallel timbers. This provides a space between them and the floor, which allows for some ventilation and cleaning.

Wood for insulating frames must be impregnated or "filled" to prevent the absorption of moisture. A satisfactory treatment consists in thoroughly drying, then painting the wood, or soaking it in boiled linseed oil and permitting it to dry, after which it can be given two coats of shellac, or other waterproof varnish. If the wood is painted only with linseed oil, it should be given three or four coats.

Where a machine direct-connected to some other must be insulated therefrom, it is necessary to insert an insulating coupling, Fig. 14, between the generator or motor and the

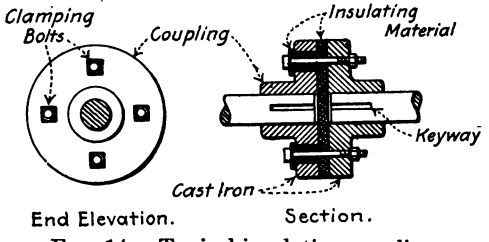


FIG. 14.—Typical insulating coupling.

other machine. Couplings of the design of Fig. 14 are frequently encountered but a great many other types are in use. Some of these couplings are of the "flexible" type in addition to being insulating couplings. In the coupling of Fig. 14 a disk of fiber is bolted between the two faces of the flange coupling and the coupling bolts are insulated with fiber washers and bushings. Where an insulating coupling is used, it is necessary to locate a bearing to support the shafts on either side of, and close to, the coupling. It is difficult to insulate a large direct-connected electrical machine from another machine which it drives, or which drives it. For this reason it is now almost the invariable practice to ground such machines, and to not attempt to insulate them.

A difference of potential due to static electricity is developed between the frame and ground where machine frames are insulated from ground, by the friction of the belt slipping on the pulleys and by the friction of the belt on the surrounding air. This "static" will often discharge from the belt driving or being driven by the machine, or may discharge from some portion of the machine to a grounded object. While such static discharges may not be dangerous to life, it has been found that they frequently have an injurious effect on the insulation used on the machine windings and sometimes cause insulation breakdowns. These static discharges may constitute a fire hazard.

A metallic comb connected to ground will discharge static electricity from a belt. It should be arranged about as shown in Fig. 15, close to, but not touching the belt from which the

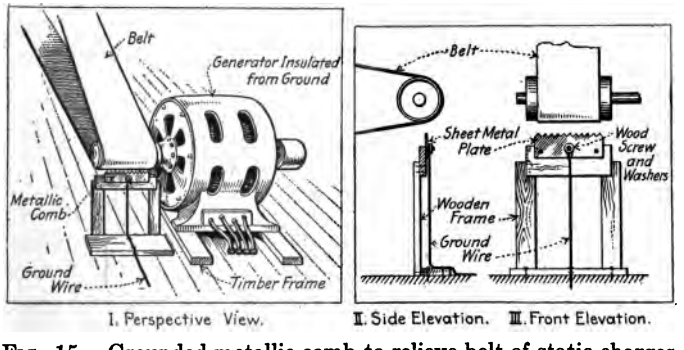


FIG. 15.—Grounded metallic comb to relieve belt of static charges.

"static" emanates. Such a comb will frequently minimize the discharges from the belt of an insulated machine. If the machine frame is grounded and the pulley is of metal a similar result will usually be accomplished. Grounding the frame of a machine or arranging a metallic comb by the driving belt will not always wholly eliminate "static"—but conditions will in nearly every case be materially improved thereby. "Static" discharges between the frame and earth are eliminated by grounding the frame.

A high-resistance path to ground for static discharges may,

where the machine frame must be insulated, be utilized. A high-resistance path can be provided as shown in Fig. 16, by using for a resistor a lead pencil mark, possibly an inch or two long and 1/16 in. wide, on a piece of ground glass. This resistor should be connected between the generator frame and ground. A metal terminal is arranged to make contact with each end of the pencil mark and to these metal terminals are connected, respectively, the leads to the ground and to the frame of the machine. Although the resistance of such a pencil mark is exceedingly high, so high that practically no current

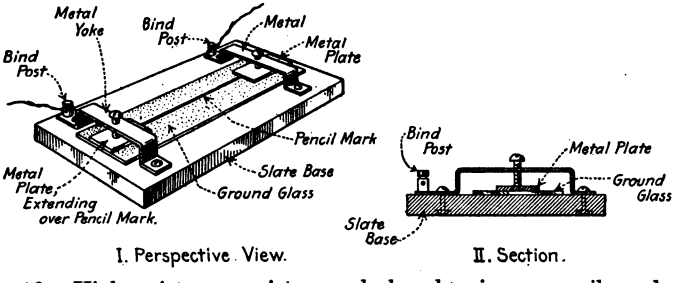


FIG. 16.—High-resistance resistor made by drawing a pencil mark on ground glass.

will be forced through it by ordinary voltages, the high-voltage "static" electricity will readily pass to ground through it and prevent the development of the difference of potential which originates static discharges between frame and ground. Metal pulleys should be used on the machine to provide a conducting path from the belt to the frame if this arrangement is to be most effective.

1*d*. ¶*I*. GENERATORS. Constant potential generators, except alternating-current machines and their exciters, must be protected from excessive current by safety fuses or equivalent devices of *approved* design.

Overload protective apparatus for generators serves to protect the machines against excessive currents. If the current through a fuse exceeds that which the fuse is designed to carry, it will rupture and open the circuit. If the current through a circuit-breaker exceeds the current for which the breaker is set, the breaker will automatically open the circuit in which it

is connected. These circuit-breakers or fuses are used to protect generators, other apparatus or conductors, against overloads or short-circuits by connecting them in series as shown in Fig. 17. Circuit-breakers are almost invariably used for the protection of large machines and are usually, though not necessarily, used for the protection of small ones. Unless some kind of overload protection is provided a short-circuit would be likely to cause a burn out of the armature of the generator feeding the circuit.

Practically all generators will carry some overload beyond their normal rating. The per cent. overload that any machine is capable of carrying and the length of time for which the overload can be carried without damage is a thing that must be ascertained in the case of each particular machine by making inquiry of the manufacturer of the machine. As a general proposition generators are so designed and rated that they will carry a 25 per cent. overload for a considerable period (usually 2 hours) without dangerous heating, hence it is frequently the practice to set the circuit-breakers protecting a generator to trip on a current 25 per cent. in excess of the normal full-load current of the machine. Where fuses are used for protection

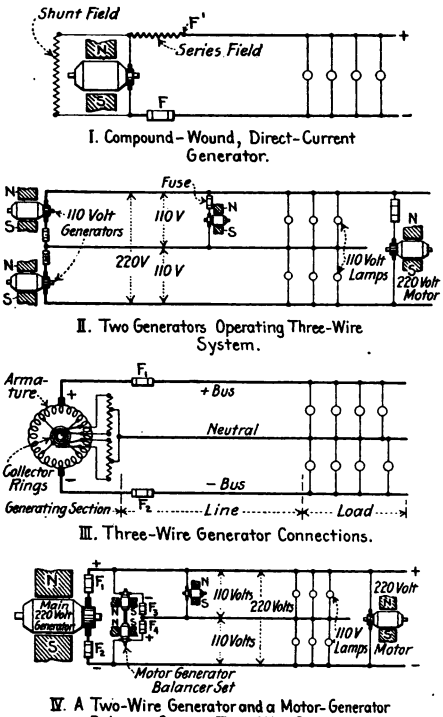


FIG. 17.—Elementary diagram indicating overload protection requirements for direct-current generators.

they are selected to pass a current 25 per cent. above the normal full-load current of the machine (see data under *Rule* 23*e*, ¶*I*, relative to the rating of fuses).

The overload protection of a direct-current constant-potential generator may be a fuse or a circuit-breaker, located between the generator and the switchboard bus bars, as shown in Fig. 18, which indicates the simplified wiring diagram for two compound-wound, direct-current, constant-potential generators. The circuit-breakers *A* and *B* constitute, respectively,

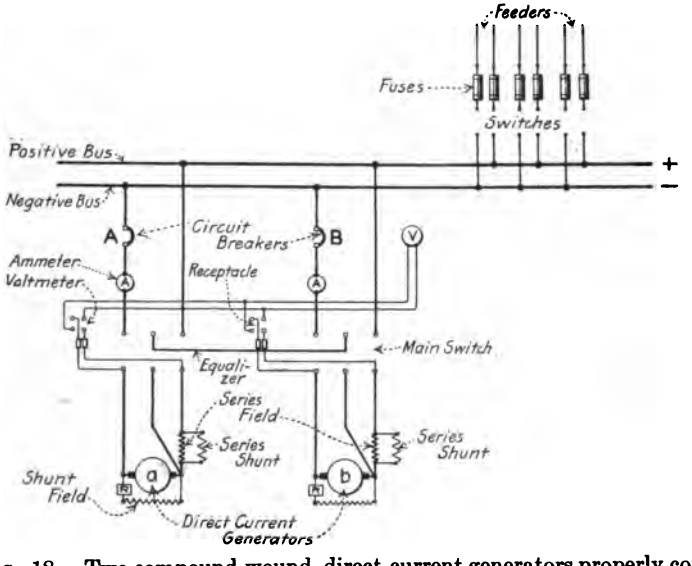


FIG. 18.—Two compound-wound, direct-current generators properly connected and protected.

the overload protection for generators *a* and *b*. If a short-circuit occurs on a line fed by a direct direct-current generator, the machine will spark excessively and in some cases the arc may form from brush to brush, that is, the machine will flash. Furthermore, the characteristics of a direct-current generator are such that, if it is short-circuited, it will force, for a short time at least, an excessive current through the short-circuit. Obviously these conditions might originate a con-

flagration when a line is short-circuited if proper overload protection is not provided. It is for these reasons that overload protection for direct-current machines is imperative. Why overload protection may be omitted from alternating-current generator leads is indicated in the following paragraphs.

Overload protection is not, as a rule, provided on alternating-current generator circuits for at least four reasons. (1) Alternating-current generators have considerable reactance in their armature circuits, which tends to prevent the sudden

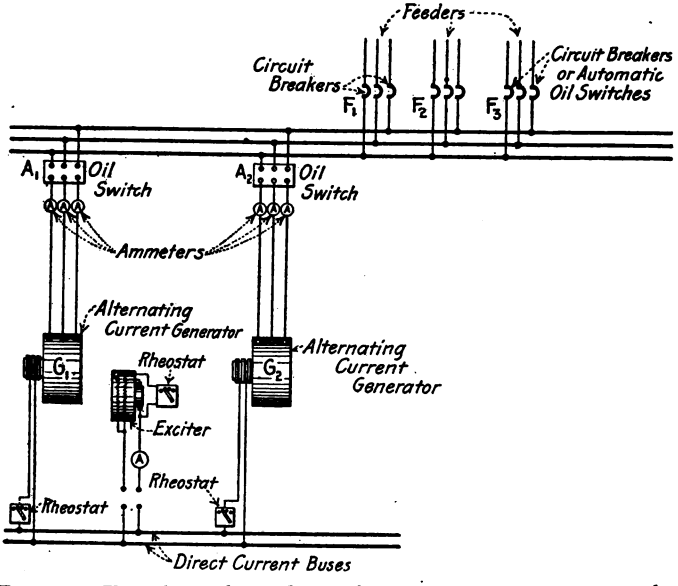


FIG. 19.—Two three-phase alternating-current generators properly connected and protected.

increase of current when a short-circuit occurs on the system. (2) If a fuse or automatic circuit-breaker were connected in the position shown at A_1, Fig. 19, and a short-circuit occurred on one of the feeder circuits, this fuse or automatic circuit-breaker might open instantly. If three generators (the third is not shown in the illustration) were operating on the same set of bus bars, generator G_1 would have to be synchronized with the other two before it could be reconnected to the buses.

The process of synchronizing is often a difficult and precise operation and may consume relatively considerable time. (3) The sudden opening of an alternating-current generator circuit frequently induces momentarily very high voltages. That is, the high electromotive forces of self-induction in the machine at the instant the circuit is opened, may be great enough to puncture the insulation of the generator. (4) If automatic protection, that is, automatic circuit-breakers or fuses, are provided in an alternating-current generator circuit they are likely to be operated by a momentary current which may interchange between generators when they are being synchronized. The operation of the protective devices at such times would cause great delay and inconvenience.

Hence alternating-current generators are usually connected to the bus bars through a non-automatic, hand-operated oil switch, A_1 and A_2, Fig. 19. Fuses or circuit-breakers are, however, provided in the feeders as at F_1, F_2, and F_3. If then a short-circuit occurs on one of these feeders, the fuses or the circuit-breaker protecting the feeder will operate and disconnect that feeder from the bus bars, but the generator will not be disconnected.

Where an alternating-current generator is short-circuited the prime mover will probably be slowed down, or if it continues to operate the voltage impressed by the machine on the line will be considerably below the normal voltage. Some alternating-current generators can be short-circuited without being affected adversely. Certain of the electrical machinery manufacturers short-circuit some of their generators (as part of the test the machine must undergo) while the generator is delivering full-load current at normal rated voltage and normal speed. In any case, if the current through the armature of an alternating-current generator becomes excessive, the trouble can usually be detected from the odor of the overheated coils and the difficulty can be relieved before permanent damage results. Since these machines do not have commutators, as have direct-current machines. with them there is no possibility of excessive arcing and flashing at the commutators at times of short-circuit.

Overload protection should be provided on a small isolated alternating-current generator, which feeds its load direct as shown in Fig. 20, because in this case, the principal objections to overload protection outlined in the preceding paragraph do not hold.

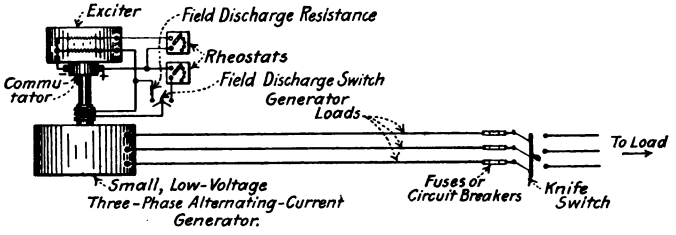


FIG. 20.—Overload protection for a small alternating-current generator.

1*d*. ¶*II*. GENERATORS. For two-wire D. C. generators, single pole protection will be considered as satisfying the above rule, provided the safety device is so located and connected that the means for opening same is actuated by the entire generator current, and the action thereof will completely open the generator circuit.

For protecting two-wire, compound-wound, direct-current generators one fuse or circuit-breaker is sufficient if it is connected (as shown in Figs. 17, *I*, and 18 and 21) in the lead not connected to the series winding. The reason that the protective device should not be in the series-winding lead will be evident from a study of Fig. 21, which shows that from the positive side of generator 1 there are two paths to the positive bus bar. One path is via the series winding as shown by the full line arrows: *ABCD* to the positive bus. The other route is via the equalizer in the series winding of the second machine as shown by the dotted line arrows: *AEFGHIJKL*. Obviously if the protective devices F_1 and F_2 were placed in leads *AD*

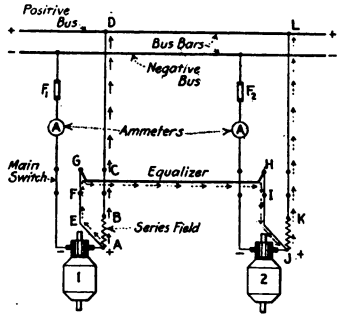
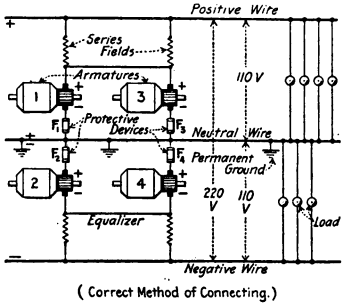


FIG. 21.—Showing the two routes for current from the positive brush of 1 to the positive bus bar.

or *JL* there would be no assurance that all of the current flowing in the armatures of the machines passed through them. In practical operation of machines some current flows through the equalizer, which means that all of the armature current does not flow through the series-field lead, for instance, through *AD* or *JL*. Where one compound-wound generator is operating independently and is never paralleled with another generator, the overload protective device may be in either lead, that is at *F* or at F_1, in Fig. 17, *I*.

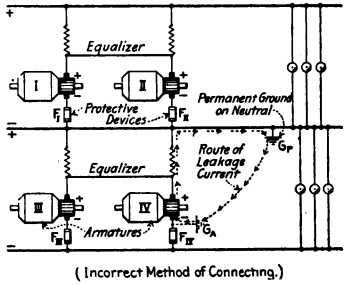
The overload protection for a shunt-wound, direct-current generator may consist of but one fuse and it can be located in either of the generator leads.

1*d*. ¶*III*. GENERATORS. For two-wire D. C. generators used in conjunction with balancer sets to obtain a neutral for three-wire systems, a protective device must be installed, which in case of the excessive unbalancing of voltages will operate to disconnect the three-wire system.



(Correct Method of Connecting.)

FIG. 22.—Schematic diagram of four two-wire generators feeding a three-wire system.



(Incorrect Method of Connecting.)

FIG. 23.—Illustrating how, when connections are incorrect a short circuit can flow without actuating the protective device.

The correct and incorrect connections for overload protection for two-wire generators feeding three-wire circuits are shown in Figs. 22 and 23, respectively. Note that in Fig. 22, which shows the correct method, the protective devices—circuit-breakers or fuses—are in every case cut in the leads from the generators which do not contain the series coils. Furthermore, the lead of each generator in which the protection is inserted connects in every case to the neutral wire

of the three-wire system. In a three-wire system the neutral wire is almost invariably (*Rule* 15*a* ¶*I*) permanently grounded.

Now if the connections of two of the generators *III* and *IV* (Fig. 23) are reversed so that the protective devices F_{III} and F_{IV} connect to the negative instead of the neutral bus, serious trouble can occur. For example, if an accidental ground (or a ground in the generator) occurred at G_A, the generator *IV* would drive a short-circuit current around the path indicated by the dotted arrows. This leakage current—and it might be of great intensity—does not pass through the protective device F_{IV}; hence the generator under these conditions is without overload protection and is likely to be burnt out or to cause a fire. With the connections correctly made as in Fig. 22 this dangerous condition cannot readily occur.

The approved method of protecting a motor-generator three-wire system is diagrammed in an elementary way in Fig. 17, *IV*.

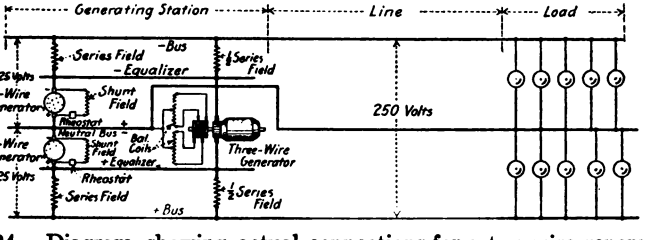


FIG. 24.—Diagram showing actual connections for a two-wire generator in combination with a motor balancer feeding a three-wire system.

This illustration does not show the series or shunt coils of the machine or the equalizer leads which are required in actual operation. The actual connections, simplified, are indicated in Fig. 24. In practical installations a circuit-breaker that will open the two outside wires and the two equalizer leads should be used for the protection of the motor-generator balancer. Frequently this protection is provided by four-pole carbon circuit-breakers or by two-pole carbon breakers with equalizer contacts, as shown in Fig. 25 for the three-wire generator, to assure the opening of both the main and the equalizer contacts in case of excessive loads. Sometimes two double-pole, double-trip circuit-breakers are used. One of them is

cut in the positive outside wire and positive equalizer lead and the other in the negative outside wire and negative equalizer lead. See the author's AMERICAN ELECTRICIANS' HANDBOOK for additional diagrams showing correct connections for overload protective apparatus for three-wire generators.

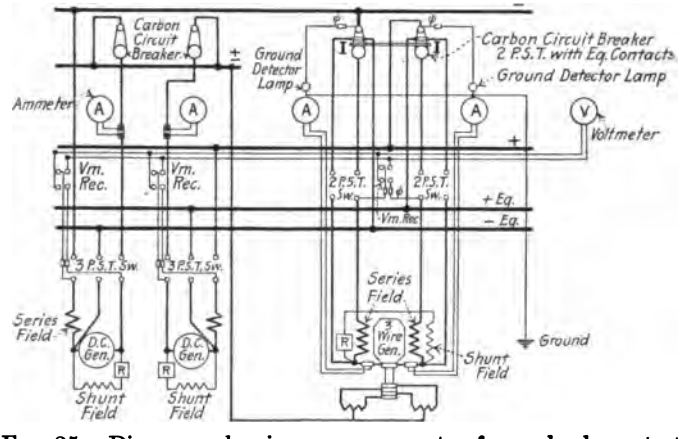


FIG. 25.—Diagram showing arrangement of overload protection equipment for a three-wire generator operating in parallel with a two-wire generator on a three-wire system.

1*d*. ¶*IV*. GENERATORS. If a generator, not electrically driven, in a two-wire system has one terminal grounded, the safety device above mentioned must be placed in the grounded lead.

Protection for a two-wire generator which is feeding a permanently grounded circuit should be in the grounded side of the circuit for the reason indicated in the diagram of Fig. 26. If the overload-protection device is placed in the ungrounded lead as at F_1 (Fig. 26, *I*) and an accidental ground, as for example G_1, occurs on the ungrounded side of the system between F_1 and the generator, it completes a short-circuit path. The short-circuit current will follow the *leakage path* shown but does not pass through F_1. With conditions thus the generator is without overload protection and is likely to be burnt out or to cause a fire. A ground on one of the windings of the generator might be equivalent to the accidental ground at G_1. If, however, the protective device is cut in the permanently

grounded side of the circuit, as at F_2 (Fig. 26, *II*) and an accidental ground occurs on the ungrounded side of the circuit, as at G_2, the short-circuit current then passes through the circuit-breaker F_2 which will cause it to open the circuit instantly. Thereby overload protection is afforded. Note that the side which contains the protective device—permanently grounded side—must also be the side that does not have the series coil in it. See a preceding paragraph (under *Rule* 1*d*, ¶*II*) for the reason.

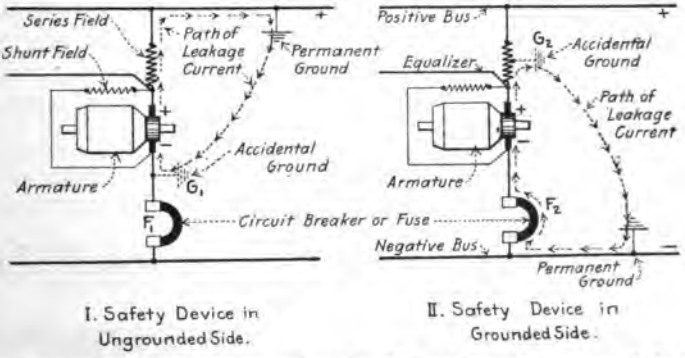


FIG. 26.—Showing why protection should be inserted in grounded side of circuit.

1*d*. ¶*V*. GENERATORS. For three-wire direct current generators compound or shunt wound, a safety device must be placed in each armature lead, and so connected as to receive the entire current from the armature. Fuses will not be acceptable. The safety device must consist of either: (1) a double pole, double coil, overload circuit breaker, or (2) a four-pole circuit-breaker connected in the main and equalizer leads and tripped by means of two overload devices, one in each armature lead.

Circuit-breakers for the protection of three-wire generators are shown in Figs. 25 and 27. Circuit-breakers must always be used for the overload protection of these machines so that the simultaneous opening of both outside wires and equalizer leads will be assured. Fuses are not acceptable because they cannot be relied upon for accomplishing this result. Fig. 28 shows the schematic connections for two three-wire interpole generators connected in parallel and Fig. 27 shows the actual

switchboard connections. If a generator on a three-wire system is disconnected from the system by the opening of a breaker and the equalizer leads are not opened simultaneously, current from other generators still connected to the system will flow back through the equalizers and run the idle generator as a motor or possibly burn out an armature.

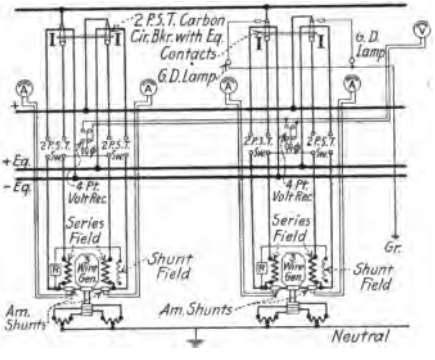


FIG. 27.—Actual switchboard connections for the connection of two three-wire generators in parallel.

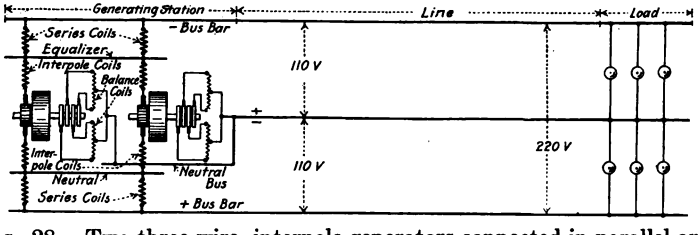


FIG. 28.—Two three-wire, interpole generators connected in parallel and feeding a three-wire system.

Protection for three-wire feeder circuits may consist of two-pole circuit-breakers, one leg of each breaker cut in each outside wire. Or instead, three single-pole circuit-breakers with a common trip attachment which insures the simultaneous opening of the three leads can be utilized. Such a circuit-breaker arrangement serves as a feeder switch and provides overload protection. For the protection and switching of small capacity feeders, three-pole knife switches combined with enclosed fuses can be used to advantage.

1*d*. ¶*VI*. GENERATORS. The safety devices above required must be so interlocked that no one pole can be opened without simultaneously disconnecting both sides of the armature from the system.

Interlocked circuit-breakers are required for the protection of three-wire generators as hereinbefore suggested. Figs. 25 and 27 show at *I*, circuit-breakers of this description connected so as to protect their respective generators. When a current in excess of that for which the breakers are set flows through the positive or negative lead of any of the three-wire generators, the breaker operates. It opens not only the positive or negative lead in which the overload current flowed but also the other main lead and the positive and the negative equalizer leads, thus entirely disconnecting the generator from the three-wire circuit.

1*e*. ¶*I*. GENERATORS. Must each be provided with a name plate, giving the maker's name, the capacity in volts and amperes, and the normal speed in revolutions per minute.

Generator name plates, Figs. 29 and 30, have tabulated on them in convenient form, the essential data regarding the

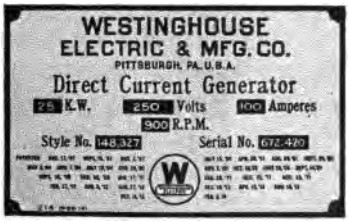


FIG. 29.—Direct-current generator name plate.

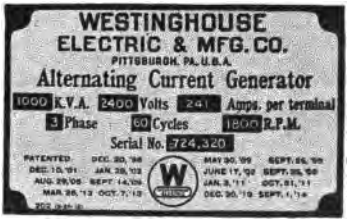


FIG. 30.—Alternating-current generator name plate.

machine. For this reason, prior to connecting a generator into a wiring system, its name plate should be studied. The name plate always indicates the normal current, and voltage and the capacity—in kilowatts for a direct-current machine, or in kilovolt-amperes for an alternating-current machine—of the generator. A generator should not be required to carry for any extended period a kilowatt or kilovolt-ampere load greater than that for which it is rated on its name plate.

Direct-current generator name plates, Fig. 29, indicate the capacity of the generators in kilowatts. The voltage shown on the name plate is that which the machine will impress at normal speed and field excitation on the two outside wires. The "amperes rating" shows the number of amperes or the intensity of current that the generator can carry continuously without being overloaded, that is, overheated. The *volts* rating multiplied by the *amperes* rating gives the *watts* rating of the machine, and this value divided by 1,000 gives the kilowatts rating. The letters "R.P.M." mean revolutions per minute, which indicate the speed at which the generator should be driven for normal operation. A machine may usually be driven at a speed 10 per cent. less or 10 per cent. greater than the name plate speed with satisfactory results.

An alternating-current generator name plate, Fig. 30, gives the rating of the generator in kva., that is, in kilovolt-amperes. The "volts" value shown on the name plate is the voltage impressed between the two wires of a two-phase generator or between any pair of the three wires of a three-phase generator. The "amp. per terminal" value indicates the current in amperes in each wire of a single-phase or of a three-phase generator. For a single-phase machine, the product of the *volts* times the *amperes* per terminal gives the *volt-amperes* capacity of the generator and dividing this value by 1,000, the *kilovolt-ampere* capacity is obtained. For a three-phase generator the product of *volts* (across outside wires) times *amperes* (per phase) times 0.577 will give the *volt-amperes* capacity of the machine. The value 0.577 is a constant used in three-phase alternating-current calculations. The "R.P.M." value on the name plate shows the speed at which the generator should be driven and with an alternating-current machine it is very essential that it be driven accurately at this speed. The "cycles" value or frequency of the generator varies with the speed at which it is driven, so unless the generator is driven at its name-plate speed, the cycles or frequency of the voltage developed by the machine will not be the name-plate frequency. Where two generators are to be connected in parallel,

their frequencies must be precisely the same, otherwise they will not operate.

Style and serial numbers on generator name plates are there marked by the manufacturer of a machine for a very important reason. When information relative to any machine is requested, or repair parts for any generator are ordered from its manufacturer it is necessary to give the manufacturer the serial number of the machine and if possible, the style or catalog number also, because all of his records relative to this machine are ordinarily filed under this serial number. Sometimes the stationary frame of the machine has one serial number and the rotating part another, which is then stamped on the commutator or collector ring end of the shaft. Where two serial numbers have thus been assigned, both should be mentioned in correspondence with the manufacturer about the machine.

1*f*. ¶*I*. GENERATORS. Terminal blocks when used on generators must be made of *approved* non-combustible, non-absorptive, insulating material, such as slate, marble or porcelain.

Terminal blocks for generators comprise the clamping arrangement or supporting frame in which the leads or terminal wires of the machine are supported as shown in Fig. 31. To connect the generator to an external circuit, conductors from the external circuit must be connected to these leads. Obviously, only insulating materials should come into contact with the leads. Furthermore, the insulating materials should be mechanically strong and immune to the effects of the ordinary oils, acids and vapors encountered in the average installation. Porcelain admirably satisfies these requirements and is extensively used for insulating bushings in generator terminal blocks; bakelite is also used. If the generator conductors are insulated with porcelain or other bushings the terminal frame or block which holds the bushings in place may be of metal.

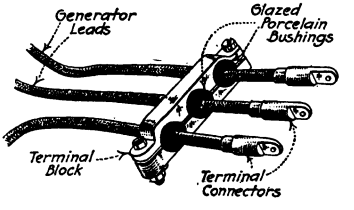


FIG. 31.—Assembly of terminal block, porcelain bushings and generator leads, for alternating-current generator.

1*g*. ¶*I*. GENERATORS. The use of soft rubber bushings to protect the lead wires coming through the frames of generators is permitted, except when installed where oils, grease, oily vapors or other substances known to have rapid deleterious effect on rubber, are present in such quantities and in such proximity to generator as may cause such bushings to be liable to rapid destruction. In such cases hardwood properly filled, or preferably porcelain or micanite bushings must be used.

2. CONDUCTORS.

(*For construction rules see Nos.* 49 *to* 57.)

From generators to switchboards, rheostats or other instruments, and thence to outside lines:

2*a*. ¶*I*. CONDUCTORS. Must be in plain sight or readily accessible.

Conductors connecting a generator to a switchboard or to measuring or control devices should always be very carefully installed. There is ordinarily no overload protection (fuses

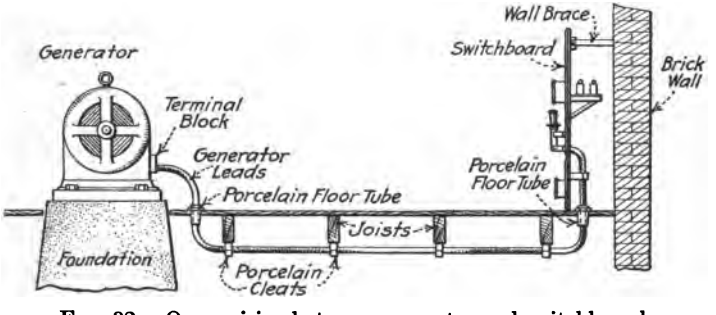


FIG. 32.—Open wiring between generator and switchboard.

or circuit-breakers) for the generator leads between the generator and the switchboard, hence a short-circuit on the generator leads at some location between the generator and the switchboard might result very seriously because of there being no fuse or circuit-breaker to open the short-circuit. It follows, therefore, that it is desirable to install all conductors between generators and their switchboards very carefully and substantially.

Conductors should be either in plain sight or accessible, so that if a short-circuit or trouble does occur, it can be readily located and corrected. Conductors between generators and switchboards should be either installed open or in conduit. Concealed knob-and-tube wiring should not be used for genera-

tor wiring because trouble in a concealed knob-and-tube circuit would be difficult or in some cases impossible of detection and even if the location of the trouble were found it would be inconvenient and expensive to make repairs.

Open-work wiring for generator leads (Fig. 32) is satisfactory where the conductors are very substantially installed, and is frequently used where there is a basement under the generator room. In installing such wiring it is desirable to place insulating supports for the conductors quite close together, possibly 2 ft. 6 in. apart, or even on every joist in a frame building, to insure against mechanical displacement.

2*a*. ¶*II*. CONDUCTORS. Wires from generator to switchboard may, however, be placed in a run-way in the brick or cement pier on which the generator stands. Where protection against moisture is necessary, cable with grounded lead sheath or grounded conduit must be used.

Where conductors cannot be run open they may be installed in runways (Fig. 33) or in conduit, Fig. 34. In every case, however, provision must be made so that the conductors can be readily withdrawn from the runway or conduit. It is good practice to assume that all generating-station conductors in conduit installed in the floor will be subjected to moisture. To protect against this moisture rubber-insulated conductors protected in lead sheaths should be used. The lead sheath should always be grounded. Even if the lead-sheathed conductor is in a metal conduit and the conduit system is grounded, an auxiliary ground wire should be connected between the lead sheath and the iron conduit. Where lead-sheath conductor is installed in a brick or concrete wireway a ground wire, at least No. 4 B. & S. gage, should be connected between the lead sheath and a water pipe, or other suitable ground. Approved ground clamps should be used, as shown in Fig. 33, for making these ground connections. Where standard rubber-insulated wire is installed in conduit in the floors and foundations of generating stations, the joints between adjacent conduit lengths should be leaded, that is, swabbed with lead paint, before being screwed up, to prevent moisture from entering the duct.

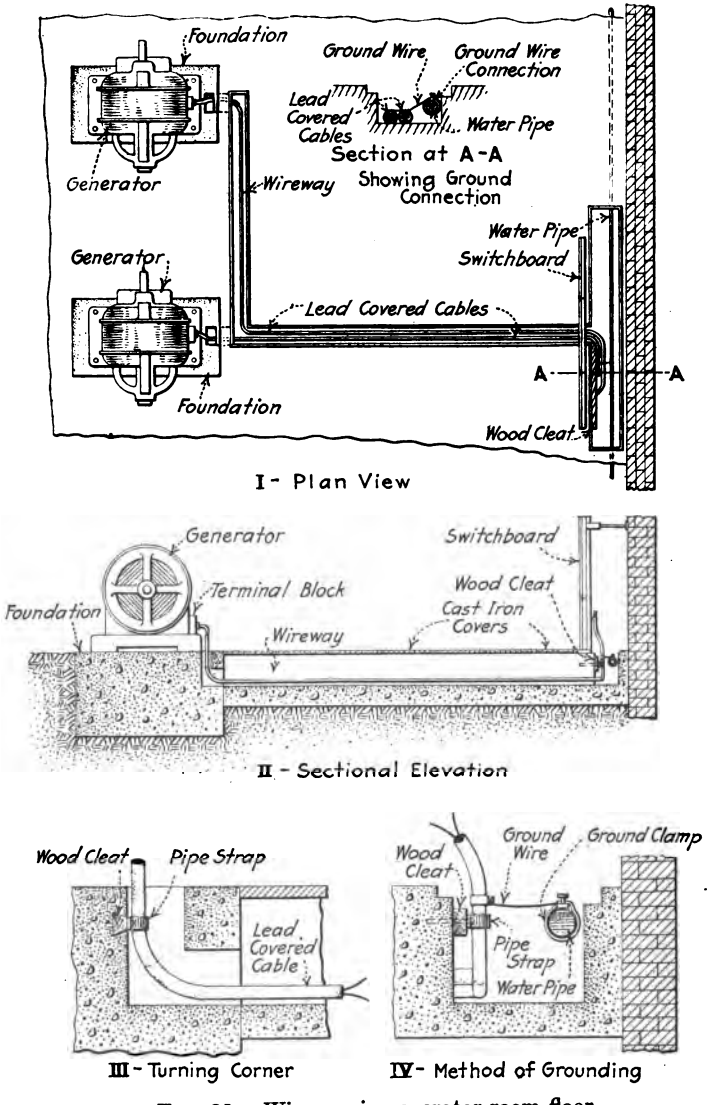


FIG. 33.—Wireway in generator-room floor.

The most satisfactory method of installing generator leads is, probably, to use rubber or varnished-cloth insulated lead-sheath conductors installed in rigid, wrought-iron conduit. While the first cost of such installations is high, it is probable that in the long run they are the most economical.

Where lead-covered conductor is used in brick or concrete wireways, that is, where it is not installed in conduit, it should be carefully placed in the recess so that its sheath will not rest on sharp corners or be subjected to abrupt bends or other mechanical abuse. Lead sheath becomes brittle when subjected to vibration and will not withstand much mechanical

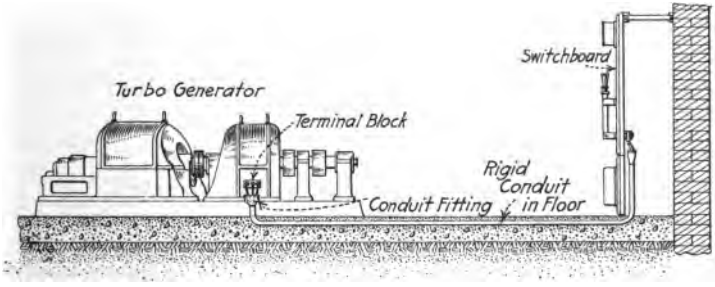


FIG. 34.—Wiring from generator to switchboard in conduit.

strain without injury. Hence in brick or concrete wireways these conductors should be well supported by pipe straps on wood cleats (Fig. 35) or by some other substantial method. They should always be held away from sharp corners or protected therefrom by a block of wood as illustrated in Fig. 35. Probably the most satisfactory construction for a brick or concrete wireway is that suggested in Fig. 36 where grooves for the lead-insulated conductors are cast in the sides of the wireway. Each lead-sheathed conductor can then rest in its own groove and be supported thereby and thus protected from any mechanical strain.

Where generator leads are installed in conduit, Fig. 34, one end of the conduit should be brought out at the floor, as close as practicable to the terminal block on the machine. The other conduit end should extend to a location back of the

switchboard and should then be carried above the floor, ending near the switch terminals to which the leads that the duct will

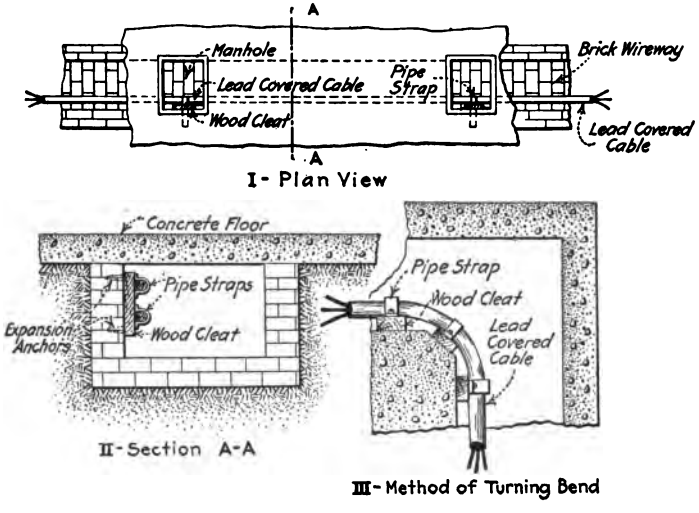


FIG. 35.—Subway under generating-room floor for conductors.

carry are to connect. By thus extending the ends of the conduit maximum mechanical protection for the conductors in it will be afforded. If rubber-insulated wire is used each end or outlet of the conduit should be provided with an approved outlet fitting. Where lead-covered cable is utilized for generator leads, all of the main conductors for the generator are ordinarily enclosed in one lead sheath, that is, for a three-phase generator a three-conductor lead cable would be used. For a direct-current generator where the equalizer lead is carried to the switchboard, a three-conductor cable would also be used.

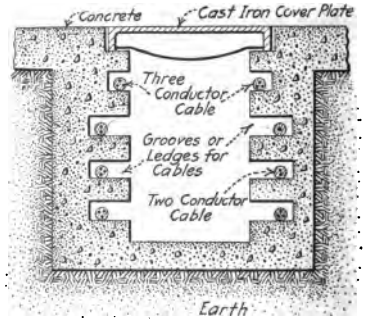


FIG. 36.—Ledges for cables in wiring trench.

If the equalizer lead is not carried to the switchboard a two-conductor lead cable would be satisfactory.

Where lead-sheath cables are used for voltages higher than 2,200 it is customary to provide a pothead, Fig. 37, at the gen-

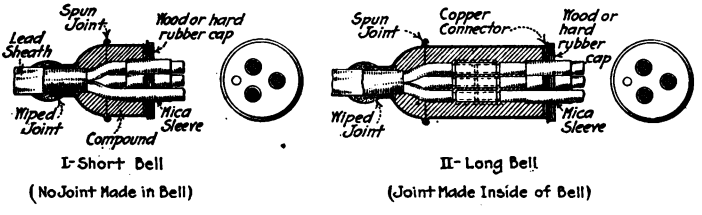


FIG. 37.—Potheads for 2400-volt cables.

erator end of the cable and also at the switchboard. Such a pothead affords the necessary insulation between the conductors where they are fanned out where they leave the cable and also prevents moisture from entering the cable. For voltages of 2,200 and lower, it will ordinarily be satisfactory to merely "fan out" and thoroughly tape the conductors, at the generator end and at the switchboard end of a lead cable. A pothead is not usually necessary with these low voltages. Where the conductor ends are to be thus "fanned out" as shown in Fig. 38, the lead casing should first be removed for a distance of about 6 in. from the end of the cable to permit the separation of the conductors. After the section of sheath has been removed, each conductor end should be "skinned" for a short distance and a suitable terminal lug soldered thereto. Then, each of the fanned-out insulated conductors should be served with a layer of friction tape and painted with a heavy coat of an insulating waterproof var-

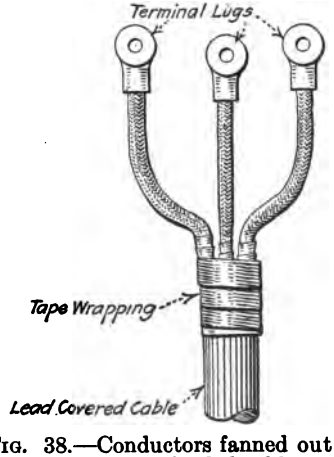


FIG. 38.—Conductors fanned out at the end of a leaded cable.

nish. In addition, as a precaution, another serving of tape should be applied around the end of the sheath from which the conductors extend, to prevent the entrance of moisture at this point. This tape serving should also be painted with the waterproof insulating varnish.

Floor channels, wireways, or trenches, as shown in Figs. 33, 35 and 36 can frequently be effectively utilized in wiring between generators and their control equipment. These channels can readily be built into concrete floors by pouring the concrete around suitable forms, but in some cases it is cheaper to make them of brick. Non-combustible lids or covers should be provided to close the openings of the trenches. These may be of steel-plate, cast-iron or concrete slabs, but should be removable. Half- or ⅜-in. steel plate makes good covers. Wood covers are sometimes used but are undesirable

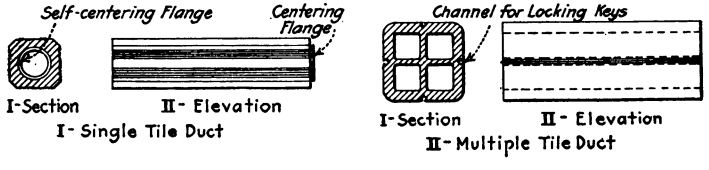


FIG. 39.—Single- and multiple-duct vitrified conduit.

because they become oil soaked and dirty and increase the fire risk. A channel for wires in the floor should have ledges formed along its upper edges to provide seats for the covers. Sometimes wireways made as shown in Fig. 35 are used. With this construction, the channel is floored over except at certain locations which should not, ordinarily, be over 25 or 30 ft. apart, where handholes, each closed with an iron cover or concrete slab, are provided. A wireway channel similar to that of Fig. 33, which can be opened over its entire length, is preferable from an installation standpoint to one of the manhole type (Fig. 35), because any portion of the channel (Fig. 33) is available for the inspection or installation of the conductors if the lid covering it is removed. On the other hand, the handhole arrangement of Fig. 35 provides a neater installation in that with it the generator-room floor is not badly disfigured by a series of channel covers.

Tile or fiber conduit can be used for carrying the generator leads. Tile conduit (Fig. 39) is satisfactory provided plenty of room is available for the installation of the duct. Tile conduit, installed, is probably more expensive than iron conduit because of the labor involved in fitting and placing it. Furthermore, iron conduit can be laid out and set in the floor form and the concrete poured around it, which results in an economical construction. Such procedure is not ordinarily feasible where tile duct is used.

2*b*. ¶*I*. CONDUCTORS. Must have an *approved* insulating covering as called for by rules in Class "C" for similar work except that in central stations, on exposed circuits, the wire which is used must have a heavy braided, non-combustible outer covering.

Flameproof coverings are required on conductors for exposed generator-room wiring to insure against the possibilities of fires that might occur due to short-circuits or grounds on the generator leads, which, as hereinbefore indicated, are not provided with overload protection. Furthermore, it frequently occurs in exposed wiring that a large number of conductors are bunched into small spaces which would greatly increase the fire hazard if conductors with combustible outer coverings were permitted. Aside from the restrictions just noted, the conductors for generator-room wiring should satisfy the same specifications as those used for wiring of any other kind of building.

The flameproofing on exposed generating-room conductors ordinarily consists of an asbestos covering or of a slow-burning braid made by saturating a woven cotton braid with a flameproof compound; see *Rules* 55 and 56. The flameproof covering may be applied over any of the regular insulating materials.

Flameproofing of conductors by wrapping them with cement-soaked cloth (Fig. 40) provides an effective method where the conductors will not be bent or disturbed after the flameproofing is thus applied. Obviously this flameproof cement coating is brittle and, therefore, will crack if it is bent. Where a conductor is to be flameproofed by this method, a strip of an absorbent cloth—like cheesecloth or linen—about 1 in. wide for conductors of ordinary diameters, is prepared. A piece of ¼-in.

hemp rope is sometimes used instead of the cloth tape. Then a neat cement mixture (Portland cement and water) is prepared of about the consistency of thick cream. The cloth tape is dipped into this neat cement and immediately served spirally around the conductor to be flameproofed as shown in Fig. 40. When the mortar dries the conductor will be encased in a hard, non-combustible cement sheath. If desirable, after one tape serving has been applied, another can be wrapped over it and then after these have partially dried, cement mortar can be molded around the conductor to any desired thickness.

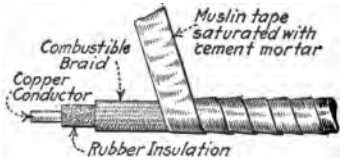


FIG. 40.—Wrapping combustible insulating covering on a conductor with muslin tape soaked in cement mortar.

2b. ¶*II.* CONDUCTORS. Bus-bars may be made of bare metal.

Bus bars (Fig. 41) may be of bare metal because, by definition, a "bus bar" is a conducting bar installed on a switchboard or in some structure in which it is protected from accidental short-circuits and grounds, and from interference.

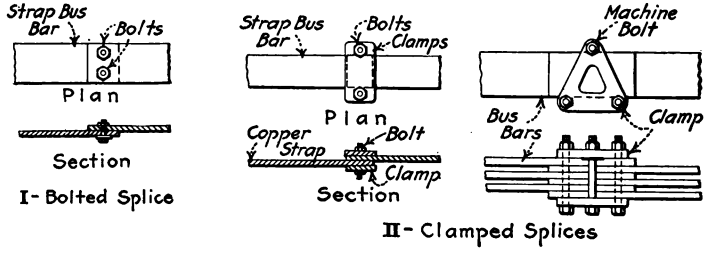


FIG. 41.—Methods of splicing bus bars.

Frequently bus bars are used in large generating stations, in lieu of generator leads, for interconnecting the generators and the switchboards, but in such cases they are always installed in channels in the floor, in tunnels or in enclosed racks specially constructed of non-combustible materials for their reception. These provisions insure non-interference and eliminate fire

risk. Bare copper bus bars have an advantage over an insulated conductor in that they radiate heat (due to electrical losses in them) more effectively.

Bus-bar metal is practically always of copper although aluminum has been used in certain cases. Strap bus bars, that is, those having a rectangular cross-section, are commonly used for large currents while cylindrical and tubular buses can be utilized where the current is relatively small. Solid wire is ordinarily used for currents up to and including 200 amp., round rod or cable for currents between 200 and 1,000 amp., and tubing for currents from 200 to possibly 600 amp. Strap bus bars are ordinarily made of copper either ⅛ in. or ¼ in. thick and of convenient width. A sufficient number of these straps or laminations is assembled into one composite conductor to provide the required carrying capacity. Ordinarily, bus bars operating at pressures below 600 volts are not insulated, but buses for voltages above 600 and below 7,000 are usually insulated with rubber, varnished cloth or similar materials. It is frequent practice to provide sufficient separation between bus bars for voltages above 7,000 so that the surrounding air will provide insulation between bars and no other insulation, except at the porcelain supports, is provided. Such bars are usually carried in specially built compartments.

Strap bus bars have the advantage that they can be readily extended and that other strap bars can be easily connected to them by simple clamps as suggested in Fig. 41.

Connections in rod-and-tube bus bars are ordinarily made with screw thread fittings similar to pipe fittings.

The safe current-carrying capacity of copper bus bars may be taken as from 750 to 1,000 amp. per sq. in. of cross-sectional area. These values are necessarily approximate inasmuch as the sectional shape of a bus bar as well as its cross-sectional area are factors in determining its carrying capacity. However, the above values are conservative. The current-carrying capacity of contact surfaces between bus bars may be taken as from 100 to 200 amp. per sq. in. of surface.

In supporting buses at switchboards the bars may be clamped in place by porcelain blocks held in brackets as shown

in Fig. 42, *II*, which shows a strap bracket rod to receive the bus bars and a similar bracket with three bus bars clamped in place. A bus-rod bracket for supporting round insulated bus bars is shown at *I*.

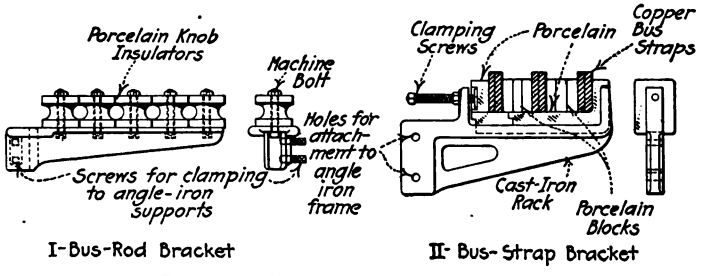


FIG. 42.—Switchboard bus brackets.

2b. ¶*III*. CONDUCTORS. Wires with inflammable outer braiding when brought close together, as in the rear of switchboards, must, when required, be each surrounded with a tight, non-combustible outer cover.

Non-combustible coverings are required for conductors that are bunched together behind switchboards because of the fire

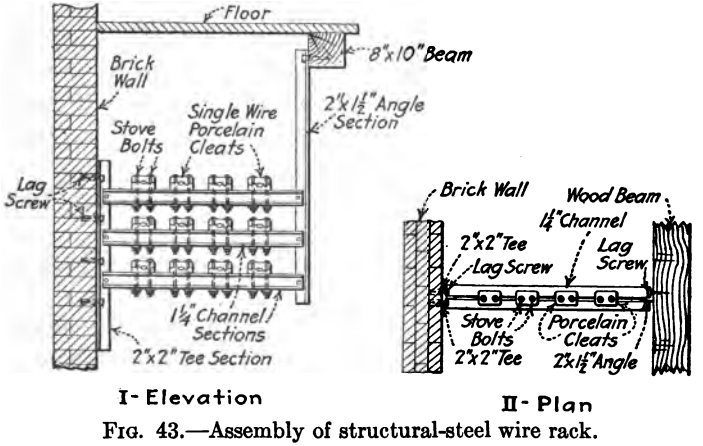


FIG. 43.—Assembly of structural-steel wire rack.

hazard that exists where a number of wires with combustible insulation are assembled. It is desirable where a number of conductors are grouped in a restricted space to install con-

ductors that are made with non-combustible insulating coverings, that is, slow-burning insulation conductors. However, if it is not feasible to install the flameproof-insulation con-

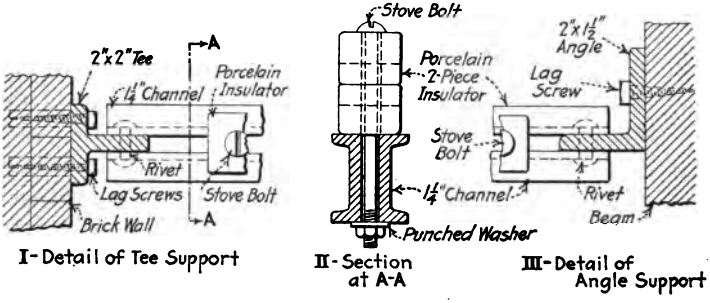


FIG. 44.—Details of structural-steel wire rack construction.

ductors, then each conductor in the group having a combustible cover should be served with a layer of asbestos or flameproof tape or should be wrapped with a plain linen or

FIG. 45.—An example of a substantial steel frame work for supporting conductors. (Media substation. Philadelphia Electric Co., Courtesy *Current News.*)

canvas tape which has been (Fig. 40) soaked in neat cement mortar.

Where it is necessary to group a large number of conductors they should be insulated on porcelain supported on iron racks.

as shown in Fig. 43, rather than bunched. A non-combustible rack can be constructed from small angle or channel structural-steel sections. If the rack is made in accordance with the method indicated in Fig. 43 and detailed in Fig. 44 the porcelain cleats can be clamped to the rack with stove bolts which pass through the slots arranged for their reception. No drilling is necessary for the accommodation of the bolts. Many variations of this steel rack construction are possible. A splendid example of steel rack construction is shown in Fig. 45. A pipe-clamp support for wiring cleats and the fittings used in connection with it are shown in Fig. 46.

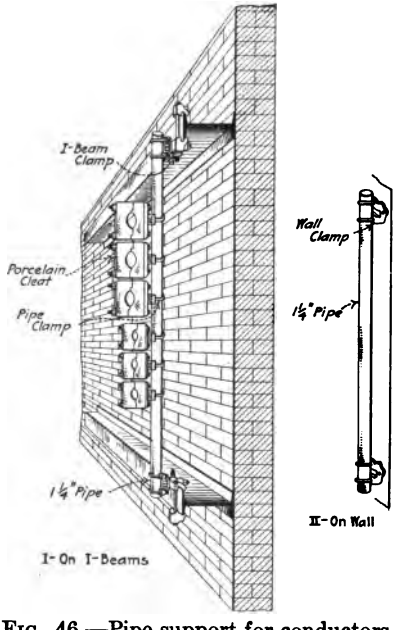


FIG. 46.—Pipe support for conductors.

2b. ¶*IV*. CONDUCTORS. Flame proofing must be stripped back on all cables a sufficient amount to give the necessary insulation distances for the voltage of the circuit on which the cable is used.

At terminals the flameproof covering of cables should be stripped back, as shown in Fig. 47, to prevent an arc-over from the terminal lug or conductor, *A*, to the flameproof covering *F*, which is a reasonably good conductor. The flameproofing should be stripped back for such a distance *D* so that this distance will be equal to the clearance distance D_1 required between conductors of oppo-

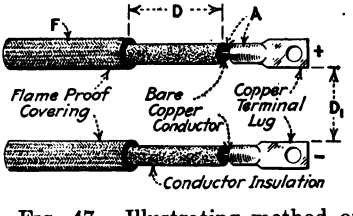


FIG. 47.—Illustrating method of stripping back flameproofing at conductor ends.

site polarity at the voltage under consideration. These clearance distances are specified in *Rule* 69*b*, "*Spacings.*" For example, on a 125-volt circuit, if the terminal lugs of Fig. 47 were mounted on a surface, the distances D and D_1 should be ¾ in. but if they were held free in air, D and D_1 could be ½ in. For 250 volts, the clearance distances specified are 1 ¼ in. and ¾ in. when supported on a surface and when held free in air, respectively.

2*c*. ¶*I*. CONDUCTORS. Must, where not in a conduit, be kept so rigidly in place that they cannot come in contact.

Conductors from generators to switchboards, rheostats or other instruments and thence to outside lines, must, whether bare or insulated, be securely supported where they are not in conduit. These requirements can be satisfied through the use of approved insulating supports which should, to be in accordance with the best practice, be held in non-combustible racks similar to those suggested in Figs. 43, 45 and 46.

2*d*. ¶*I*. CONDUCTORS. Must in all other respects be installed with the same precautions as required by rules in Class "C" for wires carrying a current of the same volume and potential.

2*e*. ¶*I*. CONDUCTORS. In wiring switchboards the ground detector, voltmeter, pilot lights and potential transformers must be connected to a circuit of not less than No. 14 B. & S. gage wire that is protected by *approved* fuses. This circuit is not to carry over 660 watts.

Approved fuses should be used in switchboard wiring installations to protect the instrument "circuits." For example, in Fig. 48, fuses are shown at F and F_1 for the protection of the voltmeter and of the ground-detector lamps. Fig. 49 shows the wiring of an alternating-current switchboard in which F_1, F_2, F_3, and F_4 are fuses protecting the ground-detector and voltmeter circuits which are served through the potential transformer P. Although wire smaller than No. 14 would in many cases be large enough to carry the currents of these instrument circuits without excessive heating, wire smaller than No. 14 should not be used because it would not have sufficient mechanical strength to insure against frequent accidental breakage.

2e. ¶*II.* CONDUCTORS. For the protection of instruments and pilot lights on switchboards, *approved* N. E. Code Standard Enclosed Fuses are preferred, but *approved* enclosed fuses of other designs of *not over two* (2) *amperes capacity*, may be used.

Fuses for the protection of switchboard instruments and pilot-light circuits can be obtained in several designs, certain manufacturers having developed special fuses for this service. A very satisfactory arrangement for protecting switchboard-instrument circuits is that of Fig. 50. This comprises a

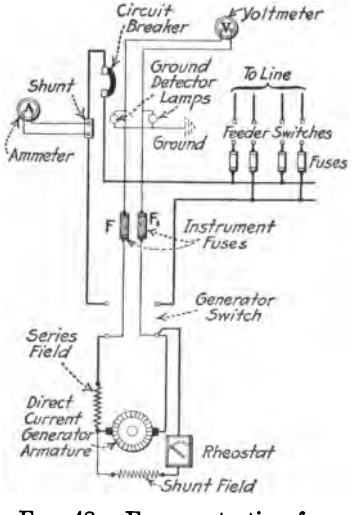


FIG. 48.—Fuse protection for voltmeter and ground detector on a direct-current switchboard.

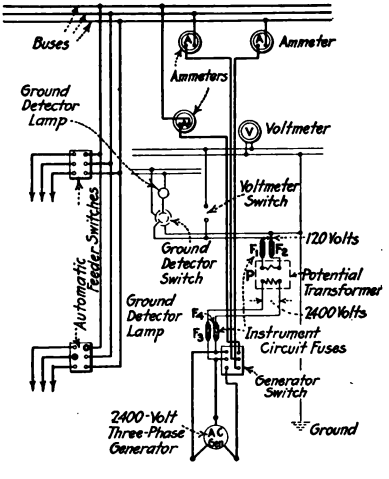


FIG. 49.—Fuse protection on instrument circuit of an alternating-current switch-board.

specially designed Edison fuse plug and an Edison plug cut-out which are arranged to accommodate the ferrule type 0–30 amp., 250-volt, NATIONAL ELECTRIC CODE Standard (*Rule* 68) fuse. The feature of this fuse plug casing and plug cut-out (which are made by the Bryant Electric Company) is that they have left-hand instead of the usual right-hand screw threads on the casing and in the shell. The ordinary Edison plug fuse casings and Edison plug cut-outs, which are approved for pressures only up to 125 volts because of the fact that

Edison plug fuses may be used in them, have standard right-hand threads. Edison plug fuses are not safe nor approved

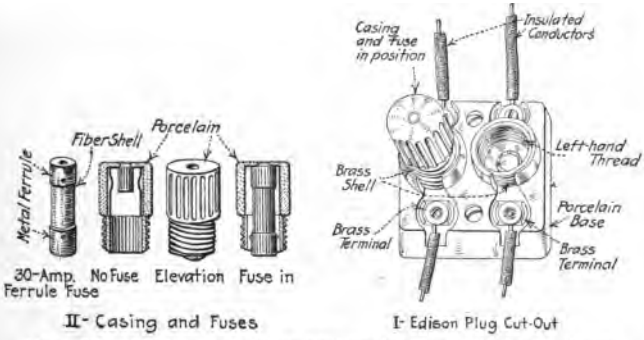


FIG. 50.—Edison fuse plug and casing for switchboard use.

for voltages exceeding 125. But the cut-out of Fig. 50, inasmuch as it has a left-hand thread, will not accommodate an Edison plug fuse, but will accommodate only the special fuse plug casing shown at *II* which can be filled only with a 250-volt fuse.

3. SWITCHBOARDS.

3*a*. ¶*I*. SWITCHBOARDS. Must be so placed as to reduce to a minimum the danger of communicating fire to adjacent combustible material.

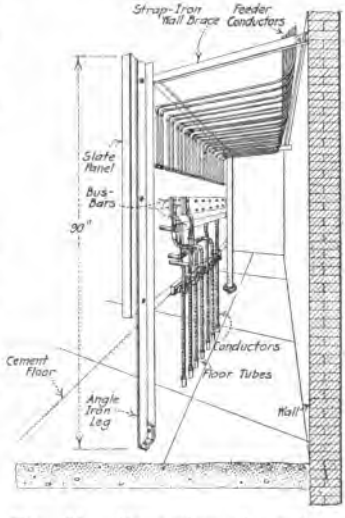


FIG. 51.—Rear view of a reliable switchboard installation.

Switchboards, unless carefully installed, constitute a fire risk, due to the fact that they support conductors (bus bars) which are frequently uninsulated. Furthermore, generator circuits, as hereinbefore described, have no overload protection between the generator and the switchboard. Hence there is a possibility of the oc-

currence of stubborn short-circuits across such unprotected conductors. It is obvious, therefore, that switchboards should be installed as far distant as possible from combustible material and that they should be erected in dry locations. It is desirable that the floor under the switchboard be of cement,

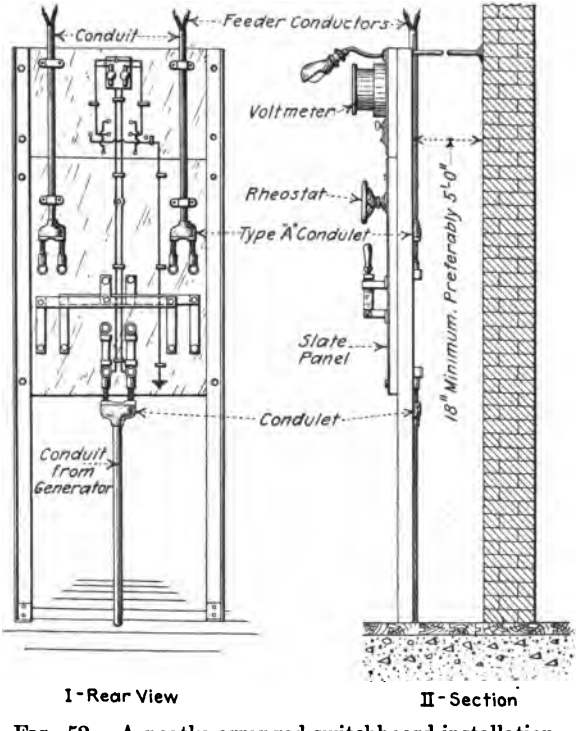


FIG. 52.—A neatly arranged switchboard installation.

brick, or other non-combustible material. Figs. 51 and 52 illustrate good examples of safe switchboard installations.

3a. ¶*II*. SWITCHBOARDS. Switchboards must not be built up to the ceiling, a space of three feet being left, if possible, between the ceiling and the board. The space back of the board must be kept clear of rubbish and must not be used for storage.

Clear space should be provided all around switchboards to minimize fire risk.—It is for this reason that it is inadvisable

to extend the boards to the ceiling because the space thus enclosed between the top of the boards and the ceiling would be likely to contain a number of concealed conductors wherein a fire might readily be started. It is for the same reason that nothing except the electrical apparatus constituting part of the switchboard equipment should be permitted in the space back

FIG. 53.—A well arranged angle-iron-frame switchboard. (Alternating-current switchboard in the Media substation of the Philadelphia Electric Co. Courtesy *Current News*.)

of the board. Fig. 53 shows an example of a well-arranged switchboard which is of the skeleton type, comprising insulating slabs mounted on an angle-iron frame.

3*b*. ¶*1*. SWITCHBOARDS. Must be made of non-combustible material.

Combustible materials should not be used in switchboard construction because of the fire risk always involved, as outlined in preceding paragraphs. Modern switchboards comprise slate or marble panels mounted on structural-steel or

iron-pipe frames. A skeleton metal-frame switchboard like that of Fig. 53 constitutes a sensible, neat, and economical arrangement.

3c. ¶*I*. SWITCHBOARDS. Must be accessible from all sides when the connections are on the back, but may be placed against a brick or stone wall when the wiring is entirely on the face.

Access to switchboards from all sides is desirable not only because of the fact that such access permits of ready installation and repair, but also because fires, provided they occur, may then be readily extinguished. Obviously, if the wiring and "live" parts are all on the front of the switchboard, as they sometimes are on small boards, there is no reason why the panel should not be mounted directly against a non-combustible wall. However, where the wall is of wood, the panel should be mounted some distance from it as shown in Fig. 54, and such a mounting is desirable, even if the wall is of non-combustible material.

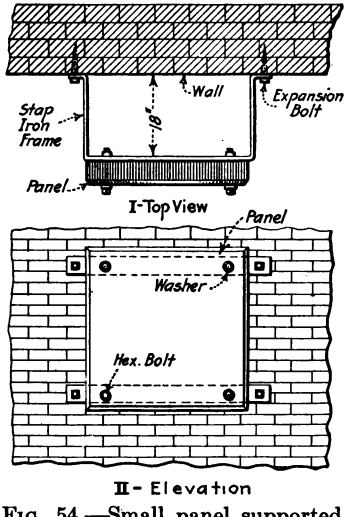


FIG. 54.—Small panel supported on wall.

3c. ¶*II*. SWITCHBOARDS. If the wiring is on the back, there must be a clear space of at least eighteen inches between the wall and the apparatus on the board, and even if the wiring is entirely on the face, it is much better to have the board set out from the wall.

A clearance of at least 1 ft. 6 in. between the wall and the furthest extending apparatus on the back of the switchboard is required for boards which have wiring on their backs. This 1 ft. 6 in. is the minimum clearance permissible. It is customary to provide a wider space. A clear space of at least 3 ft. is desirable particularly for switchboards for voltages

exceeding 250. It is frequently necessary to make alterations or repairs behind a switchboard while the board is "hot," that is, while it is in service, and at such times it is advisable, both from the standpoint of life hazard and time economy that the wiremen have plenty of room in which to work. A clearance of 5 ft. between the back face of the board and the wall is none too much for the average installation.

The enclosing of the space back of the board with metal lattices is sometimes desirable in that it precludes the storage of rubbish back of the board and prevents unauthorized persons from entering this space. Since the door in the lattice should be kept locked it may prevent the switchboard attendant from getting back of the board quickly in case of an accident there. Because of this condition it is *not* usually the practice in modern plants to thus enclose the space back of a switchboard.

3*d*. ¶*I*. SWITCHBOARDS. Must be kept free from moisture.

Where a switchboard is installed in a location where it might be subjected to moisture provision must be made to prevent the moisture from reaching the board. Not only does the moisture tend to corrode switch jaws and contacts but it collects on the conductors and switchboard surfaces and may thereby promote the formation of short-circuits and grounds. Switchboards should not, therefore, be erected near windows that remain open or under or near steam pipes or water pipes upon which condensation collects. Where there is any possibility of moisture dropping from above on a switchboard, a canopy similar to that suggested in Fig. 55 should be arranged for its protection.

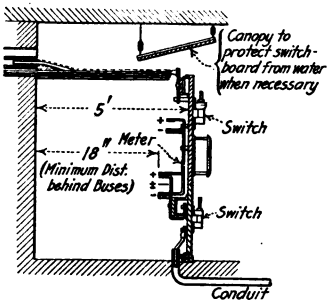


FIG. 55.—Indicating desirable clearances around a switchboard.

3*e*. ¶*I*. SWITCHBOARDS. Wires with inflammable outer braiding, when brought close together, as in the rear of switchboards, must, when required, be each surrounded with a tight, non-combustible outer cover.

Non-combustible outer coverings should be provided for conductors where they are bunched together back of switchboards in a manner similar to that described under *Rule 2b*, ¶*III* in a preceding paragraph for bunched generator leads.

3*e*. ¶*II*. SWITCHBOARDS. Flame proofing must be stripped back on all cables a sufficient amount to give the necessary insulation distances for the voltage of the circuit on which the cable is used.

Flameproofing must be stripped from the switchboard conductors at terminals for the reasons outlined under *Rule 2b*, ¶*IV*, in a preceding paragraph in connection with generator conductors, and as illustrated in Fig. 47.

4. RESISTANCE DEVICES.

(*For construction rules see Nos.* 78 *and* 79.)

4*a*. ¶*I*. RESISTANCE DEVICES. Must be placed on a switchboard, or at a distance of at least one foot from combustible material, or separated therefrom by a slab or panel of non-combustible, non-absorptive, insulating material such as slate, soapstone or marble, somewhat larger than the rheostat, which must be secured in position independently of the rheostat supports. Bolts for supporting the rheostat shall be countersunk at least one-eighth inch below the surface at the back of the slab and the bolt heads shall be covered with insulating material. For proper mechanical strength, slab should be of a thickness consistent with the size and weight of the rheostat, and in no case to be less than one-half inch.

Resistance devices comprise rheostats, resistors, motor starters, controllers, regulators, arc lamp compensators, and similar appliances. A typical direct-current starting rheostat is illustrated in Fig. 56. Practically all appliances of this type develop and radiate a certain amount of heat when they are in operation. The amount of heat generated is determined, to a great extent, by the severity of the service imposed. Under unusually severe conditions a resistance device may become excessively hot, even red hot in extreme cases, and may throw off sparks.

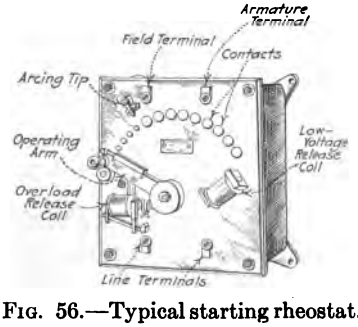


FIG. 56.—Typical starting rheostat.

or particles of red hot metal when its controlling lever is moved. A consideration of this fact indicates that any resistance device constitutes a source of fire risk and that every precaution should be taken in its installation to protect against possible dangers from this cause.

Individual insulating bases, Fig. 57, should (where the resistance device is supported on a surface of combustible material) be provided between the burnable material and the resistance appliance. Such a base should extend at least 2 in. or 3 in. beyond each side of the resistor frame, that is, the insulating base should be at least 4 in. longer and 4 in. wider than the face of the device which rests against the insulating slab. Although slabs are permitted of a minimum thickness of ½ in., no slab should be thinner than 1 in. and 1½ in., is a more satisfactory thickness in that it will practically insure against breakage under ordinary conditions. Slate, free from metallic veinings is, for low voltages, a better material for such slabs than marble, because it is stronger. The screws or bolts holding the device to its insulating base can be countersunk as shown in Fig. 57. The plugging of these countersunk holes after the bolts are in place with sealing wax or similar material is to prevent the possibility of the bolts contacting with the conducting supporting surface and thereby grounding the frame of the resistance device.

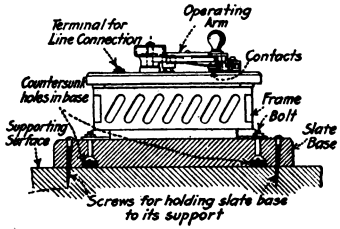
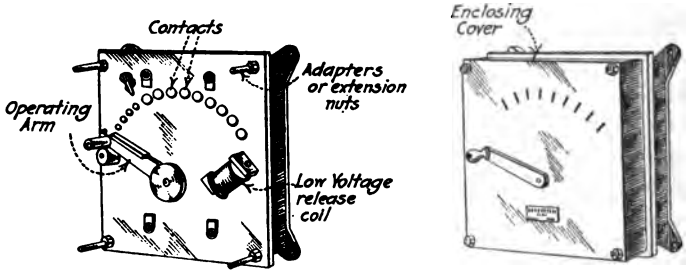


FIG. 57.—Illustrating method of supporting rheostat.

4a. ¶II. RESISTANCE DEVICES. If resistance devices are installed in rooms where dust or combustible flyings would be liable to accumulate on them, they must be equipped with dust-proof face plates.

Dustproof covers should be provided on resistance devices installed in certain locations. Where the air is laden with dust, flying lint, or other combustibles, it is apparent that there is a possibility of the arcs, which are almost always produced when the rheostat lever is pulled across its contacts, igniting

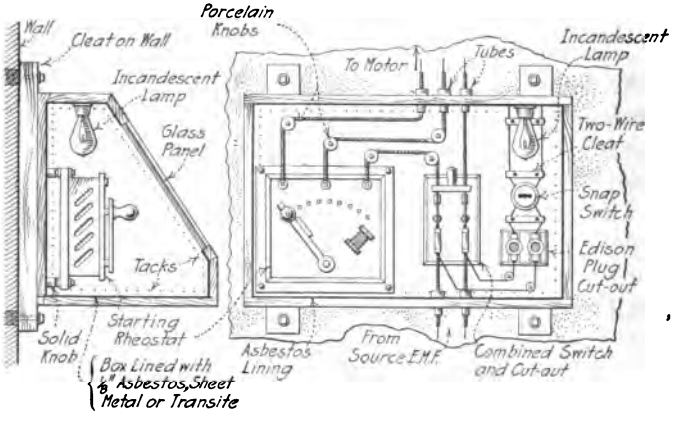
these particles and causing a fire. If a dustproof cover is provided for the rheostat as shown in Fig. 58, the possibility



I-Rheostat Ready to Attach Cover II- Face-Plate Cover in Place

FIG. 58.—Rheostat face-plate cover.

of such an accident is minimized. The "live" lever of the rheostat and its contact buttons are enclosed within the pressed-metal cover, but a "dead" operating lever, which



I- Section II-Elevation

FIG. 58a.—A cabinet for a starting rheostat located in a dirty place. (It would be better construction if the fused switch shown were of the type and arranged as diagrammed in Fig. 201, *II*, so that its blades would be dead when open and so that the fuses would protect the switch.)

engages with the contact lever, is accessible from the outside. The cover is supported on four studs and can be removed and

replaced readily when it is desirable to inspect the contacts or the operating arm.

In general, enclosures for starting devices should be steel boxes, and should be ventilated and waterproof. Snap switches—which are enclosed—should be used in preference to knife switches for small motors.

The details for an enclosing case for a motor-starting rheostat located in a dirty or moist place are shown in Fig. 58*A*. A glass panel is provided in the door, enabling the operator to note the position of the starting rheostat handle, and whether the switch is open or closed. The incandescent lamp is provided so that there will be light inside of the box for inspection and repairs. Note that the lamp is tapped in on the line side of the motor cut-out so that even if the fuses protecting the motor "blow" the interior of the box may be lighted. In a location that tends toward dampness the incandescent lamp may be permitted to burn continuously. It will then usually dissipate sufficient heat to keep the interior of the box dry. The front of the box is inclined so that the door will always tend to close itself.

4*b*. ¶*I*. RESISTANCE DEVICES. Where protective resistances are necessary in connection with automatic rheostats, incandescent lamps may be used, provided that they do not carry or control the main current nor constitute the regulating resistance of the device.

An incandescent lamp protective resistance is diagrammed in Fig. 59. Ordinarily the solenoid of an automatic rheostat is so designed that it will carry continuously its normal operating current without excessive heating. In some cases, however, the solenoid will not carry its maximum operating current continuously and in such instances a protective resistance such as an incandescent lamp is arranged in the circuit as shown in Fig. 59 to protect the solenoid coil. The operation of the automatic rheostat diagrammed is as follows:

Assume that it is desired to start the motor M. The main switch S is first closed, the starting switch S_1 being open and the contact spring which is attached to the plunger, bridging across the dead contacts C_1 and C_2. Now the starting switch

S_1 is closed and current will flow through the solenoid coil. The solenoid will thereby become magnetized and pull the plunger up. This raises the contact spring into contact with C_3 and C_4. This permits current to flow through the armature circuit (indicated by heavy lines) in which the starting resistance is arranged in series. The solenoid coil continues to pull on the plunger and draws the contact spring up, bridging it successively across each pair of contact blocks, thereby cutting the resistance out of the armature circuit. This permits the motor to attain normal speed. As the contact spring reaches the top position across C_5 and C_6, whereby all of the resistance is cut out of the motor circuit, the upper end of the plunger P simultaneously raises the contact disk A, which connects the incandescent lamp in series with the solenoid.

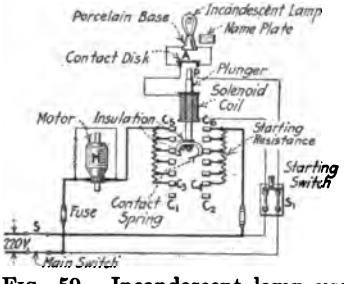


FIG. 59.—Incandescent lamp used as a protective resistor.

The introduction of the resistance of this lamp limits the current through the solenoid.

EXAMPLE.—Assume that the resistance of the lamp is 220 ohms and the resistance of the coil of the solenoid is 5 ohms. Before the contact disk was raised the current through the solenoid coil on this 220-volt circuit was: 220 *volts* ÷ 5 *ohms*, or 44 *amp.*, a relatively large current. This current is capable of raising the plunger against gravity and overcoming the friction of the contact spring against the contact blocks. However, with the contact disk A raised, the resistance in the circuit is: 5 *ohms* + 220 *ohms* = 225 *ohms*, and then the current through the solenoid coil is 0.98 *amp.* This small current would not be capable of raising the solenoid plunger, but is capable of holding it in place after it is raised. Furthermore, while the solenoid coil is capable of carrying this current of 0.98 amp. indefinitely without excessive heating, it would not be capable of carrying indefinitely the current of 44 amp. which was required for raising the plunger.

A dash pot (not shown) is provided on these automatic

resistance devices to prevent the plunger from raising too suddenly under the action of the energized solenoid. Note also that through the application of the protective resistance there is a saving of electrical energy.

4*b*. ¶*II*. RESISTANCE DEVICES. When so used, lamps must be mounted in porcelain receptacles upon non-combustible supports, and must be so arranged that they cannot have impressed upon them a voltage greater than that for which they are rated. They must in all cases be provided with a name-plate, which shall be permanently attached beside the porcelain receptacle or receptacles and stamped with the wattage and voltage of the lamp or lamps to be used in each receptacle.

4*b*. ¶*III*. RESISTANCE DEVICES. Under special authorization in writing, given in advance, incandescent lamps may be used for the purpose of resistances in series with other devices when mounted in porcelain receptacles upon non-combustible supports and so arranged that they cannot have impressed upon them a voltage greater than that for which they are rated.

An example of incandescent lamps used for resistance is shown in Fig. 60, wherein a group of five lamps is inserted in

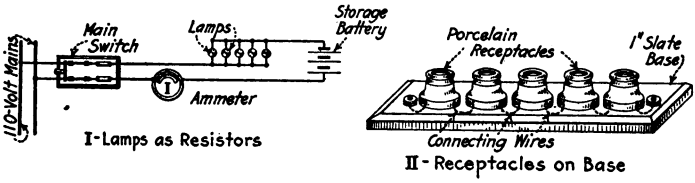


FIG. 60.—Incandescent lamps used as resistors.

series with a small storage battery across a 100-volt circuit to reduce the circuit voltage to one suitable for charging the battery. The method of mounting the porcelain lamp receptacles on a non-combustible slate base is shown at *II*. Receptacles designed for 220 volts should never be used on circuits of pressures greater than this, and receptacles constructed in accordance with 660-volt requirements should never be used on circuits operating at voltages in excess of 600.

4*c*. ¶*I*. RESISTANCE DEVICES. Wherever insulated wire is used for connections between resistance elements and the contact device of a rheostat, the insulation must be non-combustible or "slow-burning."

For large rheostats and similar resistances where the contact devices are not mounted upon them the connecting wires having "slow burning" insulation may be so arranged in groups that the maximum difference of potential between any two wires in any group shall not exceed seventy-five volts. Each group of wires must either be mounted on non-combustible, non-absorptive insulators giving at least one-half inch separation from surface wired over, or, especially where it is necessary to protect same from mechanical injury, each group of wires may be encased in approved flexible tubing and placed in approved conduit, the flexible tubing to extend at least one inch beyond the ends of the conduit.

The wiring between the resistance elements and the contact device of a rheostat is shown in Fig. 61. All of the con-

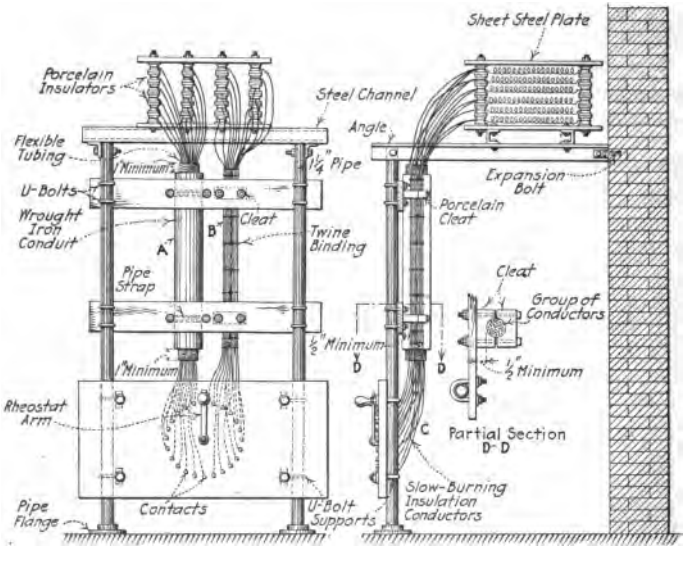


FIG. 61.—Wiring between resistor group and face plate.

ductors, *C*, have slow-burning insulation. The maximum voltage possible across this rheostat is 110, but the conductors are divided into two groups, *A* and *B*. Obviously, the maximum potential difference in either of the groups is 55 volts. Thus the requirements of the *Rule* 4c, ¶*I*, are more than satisfied. Group *B* is clamped in a porcelain cleat which supports it ½ in. from the surface wired over. Group *A* is

carried in flexible tubing, which is in turn encased by wrought-iron conduit, the tubing extending 1 in. beyond the ends of the conduit.

5. LIGHTNING ARRESTERS.
(For construction rules see No. 82.)

A lightning arrester is a device which offers a path to ground of little opposition of lightning-discharge or other static-disturbance currents, but which at the same time prevents the

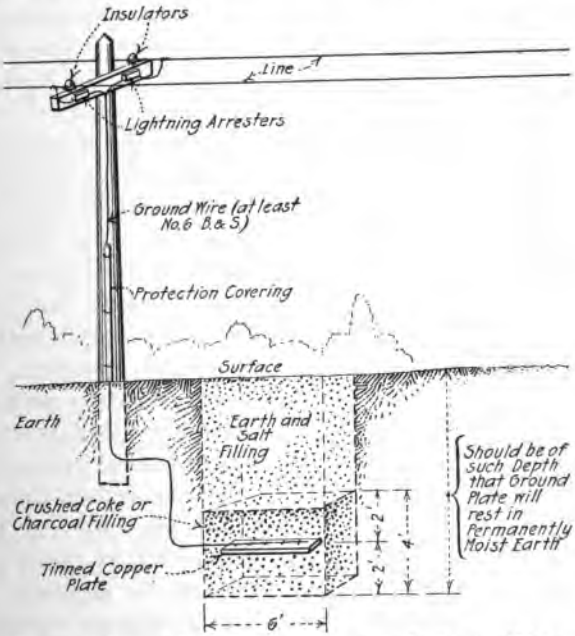


FIG. 62.—Pole-line lightning arrester installation. (*Note.*—Ground pipes are usually installed instead of plates for earth connections for line arresters.)

flow of currents impelled by the normal voltage of the circuit to which it is connected. It should be understood that a lightning arrester does not necessarily "arrest" lightning. The protection afforded is not infallible, but does, with standard makes of lightning arresters, greatly minimize the risk of lightning damage.

5a. ¶I. LIGHTNING ARRESTERS. Must be attached to each wire of every overhead circuit connected with the station.

Lightning arresters on pole lines, should, on low-potential lines be installed about as shown in Fig. 62. In localities subject to lightning disturbances it pays to locate arresters not only at the station but at numerous points along the line. The function of these line lightning arresters is to protect the transformers, if there are such, and the service wires to the buildings and to intercept the static disturbance current before it travels along the line to the station. It is considered good practice to place the arresters at intervals along the line of from 1,500 ft. to 2,000 ft., more or less. Where an overhead line joins an underground cable, an arrester should be located within 200 ft. of the junction. It is desirable, where possible, to place line arresters at points where several overhead lines join because then a discharge intercepted by any one of the lines may reach ground through the arrester.

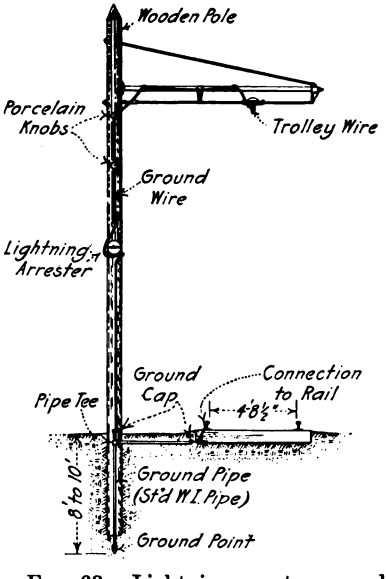


FIG. 63.—Lightning arrester ground on an overhead trolley line, wrought-iron pipe being used for making the ground.

It is claimed by the General Electric Company that effective protection of distributing transformers against lightning and static disturbances can be attained only through the installation of a suitable lightning arrester on each wire of the transformer primary circuit, on the pole on which the transformer hangs. It is asserted that if a lightning arrester is located even one pole away, the difference of potential stress on the transformer due to a lightning disturbance may be double that which

would obtain were the arrester on the same pole with the transformer. Fig. 63 illustrates one method of installing a lightning arrester for the protection of a trolley wire; the ground-pipe cap and point used in this installation are illustrated in Fig. 156 and the method of their application is discussed in the accompanying text.

5b. ¶*I.* LIGHTNING ARRESTERS. Must be located in readily accessible places away from combustible materials, and as near as practicable to the point where the wires enter the building.

In locating station lightning arresters it is obvious that they should be placed as close as possible to where the conductors protected enter the building so that the unprotected wiring

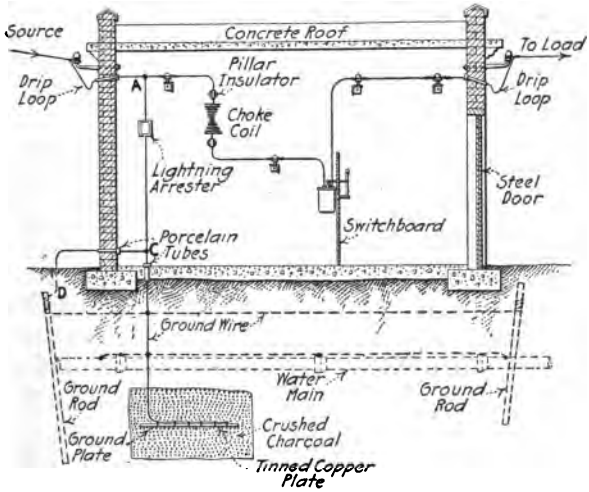


FIG. 64.—A switching station having a well-arranged lightning arrester installation.

within the building will be a minimum. Frequently there is formed, particularly with arresters of certain types, a destructive and vicious arc when a lightning current passes to ground through the arrester. It is for this reason that inflammable materials should not be permitted to remain near an arrester. Fig. 64 shows diagrammatically a typical lightning arrester installation. Only one wire of the circuit is indicated but all

of the wires of the circuit should be protected as shown. Note that the ground connection comprises plate, pipe and water main grounds.

5b. ¶*II*. LIGHTNING ARRESTERS. In all cases, kinks, coils and sharp bends in the wires between the arresters and the outdoor lines must be avoided as far as possible.

The lead connecting a lightning arrester between the line and ground should be as straight as feasible, because curves, bends or twists may introduce exceedingly great opposition to the lightning-discharge currents in the circuit. For example, the lead *AC*, Fig. 64, to ground is shown as straight as it is possible to make it. Obviously, therefore, lightning arresters should not, as a rule, be mounted on switchboards but should be independent thereof and as suggested in a preceding paragraph, and located as close as possible to the point where the conductors enter the building.

5c. ¶*I*. LIGHTNING ARRESTERS. Must be connected with a thoroughly good and permanent ground connection by metallic strips or wires having a conductivity not less than that of a No. 6 B. & S. gage copper wire, which must be run as nearly in a straight line as possible from the arresters to the ground connection.

The importance of effective ground connections for lightning arresters can scarcely be over-estimated, because experience has shown that the resistance of the ground or earth connection may largely determine the effectiveness of a lightning-protection equipment.

A lightning-arrester ground lead, that is, the conductor or wire, for example, *AC* or *ACD*, Fig. 64, in which the arrester is connected between the line and ground, may from a theoretical standpoint be of practically any reasonable cross-section, or of practically any metal. However, since all other metals are either too expensive or corrode too readily, copper is the only material that should be used for ground wires in central stations and it is advisable, where it is feasible, to always use copper elsewhere. Theoretically, the greater the exposed surface of a conductor for a given cross-section, the better carrier it should be for lightning-discharge currents.

It follows, therefore, that metal strap or tubing (see following paragraph) is better, theoretically at least, than round wire for this purpose. However, experience has shown that round copper wire, provided it is not too small, will usually answer all requirements.

A wire smaller than No. 6 A. W. G. should never be used for a lightning-arrester ground conductor because this size provides the minimum mechanical strength and conductivity advisable. It is better to use larger ground wires, particularly in important installations. In many cases a ground lead of No. 0 A. W. G. wire is used. This would be equivalent to a copper strap 1/8 in. by 21/32 in. (approximately). Ground leads of drawn-copper tubing have been used to some extent in important installations. Since skin effect may be pronounced in a conductor carrying a lightning-discharge current, the metal at or near the center of a solid cylindrical conductor may be ineffective in conveying the current. It follows that instead of using solid conductors, it is better, theoretically, to use tubular conductors so that the maximum amount of metal in the conductor will be effective. The tubular conductor has the advantage of being stiffer with a given weight of metal than a solid one. However, tubular conductors sometimes offer mechanical disadvantages and are not, usually, as readily installed as those of stranded cable.

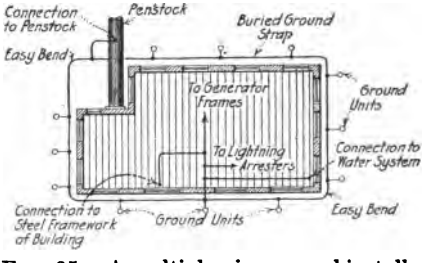


FIG. 65.—A multiple-pipe ground installation for a hydro-electric station.

Ground connections for lightning arresters may be made in accordance with any one of a number of methods which are described and illustrated under *Rule* 15*c*, *d*, etc. Information, given under *Rule* 1*c*, ¶*I*, relating to the grounding of generator frames may also be of interest.

A typical multiple-connection ground for central-station lightning arresters is shown in Fig. 65. The multiple-pipe

arrangement illustrated is described in detail under *Rule* 15*g*, ¶*V*, *Note*. The 12 ground rods, each about 10 ft. long,

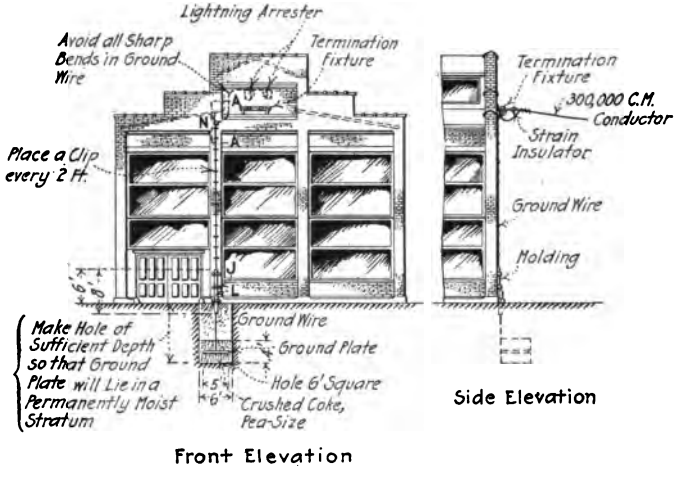


FIG. 66.—Assembly of lightning-arrester installation. (This illustration shows the ground wire protection extending only 6 ft. above the ground although Rule 15*e*, ¶*I*, specifies 7 ft.)

are distributed around the outside of the station and are interconnected by a length of heavy strap copper or copper wire. Each of the ground pipes should be driven and prepared as

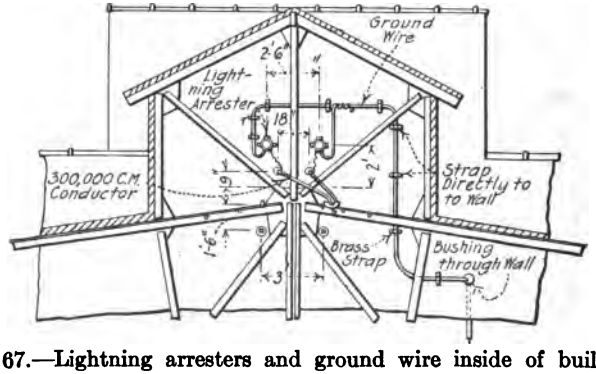


FIG. 67.—Lightning arresters and ground wire inside of building.

described and illustrated under *Rule* 15*g*, ¶*V*, *Note*. Note that auxiliary connections are attached to the steel framework of the building, to the water-pipe system, and to the steel penstock.

A complete lightning-arrester and ground-connection installation for a 250-volt industrial plant is shown in Fig. 66. The ground wire connecting the two arresters is carried down

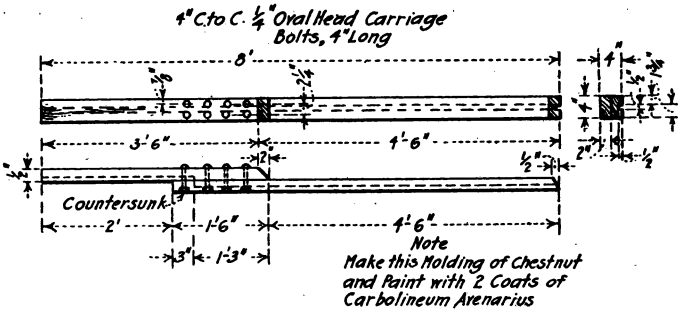


FIG. 68.—Wooden molding for protection of lightning arrester ground wire. (This molding should be 1 ft. longer to comply with the requirements of Rule 15*e*, ¶*I*, *Note*.)

inside of the building, Fig. 67, to a point *N*, Fig. 66, where it is brought through the wall and led down the outside of the building to the ground plate. The ground wire is clamped to its supporting surface by brass clips, spaced 2 ft. between centers, down to a point within 7 ft. from the sidewalk level. From this location it is protected to a point 2 ft. below the sidewalk level by wooden molding, Fig. 68. The function of the molding is to protect the conductor from mechanical injury and to prevent the accidental contact of pedestrians with the ground wire, which may under certain conditions become charged and thereby endanger life. Fig. 69 details the method whereby the ground lead was carried through the wall at the point *N*. Insulation of the ground lead from the wall is, of course, not necessary, but the porcelain tubes were used to prevent

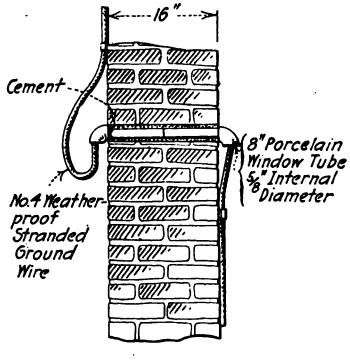


FIG. 69.—Porcelain tubes used to protect ground wire where it passes through wall.

moisture from entering around the lead, and to give the wire an "official" appearance to prevent interference by unauthorized persons.

5c. ¶*II*. LIGHTNING ARRESTERS. **Ground wires for lightning arresters must not be attached to gas pipes within the buildings nor be run inside of iron pipes.**

Ground wires should not be connected to gas pipes within buildings because there is always the possibility of a spark or arc between lengths of a gas pipe so connected, due to a faulty coupling or a rusty joint. Such an arc might ignite the gas and cause a fire. Furthermore, the discharge might, instead of following around the metal work of a meter, jump directly across portions of it and cause an explosion.

Ground wires should not be run inside of iron pipes unless the ground wire is electrically connected to the tube at the point where the conductor enters it. If the electrical connection is omitted, the iron pipe encasing the wire will greatly increase the reactance of the ground lead, thereby causing it to have immense opposition to the high-frequency lightning-discharge currents.

5d. ¶*I*. LIGHTNING ARRESTERS. **All choke coils or other attachments, inherent to the lightning protection equipment, shall have an insulation from the ground or other conductors equal at least to the insulation demanded at other points of the circuit in the station.**

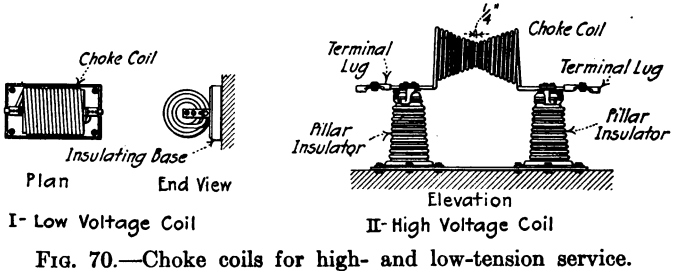


FIG. 70.—Choke coils for high- and low-tension service.

The function of a choke coil (see Figs. 64 and 70) is to provide a certain amount of reactance in a circuit between the outside line and the apparatus which the lightning arrester is to protect. Reactance offers great opposition to lightning-

discharge currents and hence tends to force them to take a path through the lightning arrester to ground, rather than through the apparatus in the station to ground.

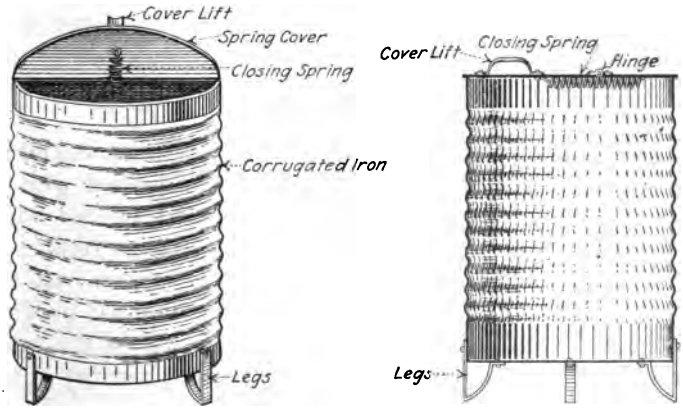
Choke coils must be thoroughly insulated. The insulation may, for a low-voltage choke coil, be provided by the base on which the coil is mounted. High-tension choke coils are supported on insulating pillars as shown at Fig. 70, *II*. The choke coil is always, as shown in Fig. 64, connected directly in the line. Hence it is at line potential whenever the circuit is "alive."

6. CARE AND ATTENDANCE.

6*a*. ¶*I*. CARE AND ATTENDANCE. A competent man must be kept on duty where generators are operating.

6*b*. ¶*I*. CARE AND ATTENDANCE. Oily waste must be kept in *approved* waste cans and removed daily.

An approved oily waste can is shown in Fig. 71. A spring is provided which makes it impossible for the cover to remain open unless it is forcibly restrained.



I-Perspective View II-Section

FIG. 71.—Approved "Safety" can for oily waste.

7. TESTING OF INSULATION RESISTANCE.

7*a*. ¶*I*. TESTING OF INSULATION RESISTANCE. All circuits except such as are permanently grounded in accordance with No. 15 must be provided with reliable ground detectors. Detectors which indi-

cate continuously and give an instant and permanent indication of a ground are preferable. Ground wires from detectors must not be attached to gas pipes within the building.

Accidental grounds on wiring or distribution systems are likely to occur in spite of all precautions. In practically every electric wiring or distribution system there are certain conductors which should normally be free of all connection with the earth, that is, free from grounds. In installing such systems every reasonable effort is ordinarily made to prevent such connection—accidental or otherwise—between the system and the earth. Such connection may occur directly between the wiring system and the earth, or it may be due to the contact of some member of the wiring system with a conductor which connects with the earth. Thus porcelain or glass insulators should be used to support conductors away from the surface on which they are carried or from adjacent objects, and porcelain tubes are used where the conductors pass near pipes or through walls or partitions. Furthermore, rubber-insulated conductors only should be utilized in concealed locations. In conduit work rubber-insulated conductors are used to prevent the grounding of these conductors on the metallic conduit system, which is itself connected with the earth.

In spite of precautions, electrical conductors which should be normally insulated from ground sometimes contact with it. These accidental grounds may occur where insulated wires have become displaced or lie against damp walls or timber, or against some piece of metal work which is in contact with the earth. Ordinarily one ground on a wiring system will produce no adverse effects but if another ground occurs on the other side (that is, on a conductor of the opposite polarity) of the system then a short-circuit or current leakage will result and interruption of service and fire may possibly follow.

The function of a ground detector.—It is obvious then that it is always desirable to keep a system entirely free of grounds. The function, therefore, of a ground detector is to indicate when a ground occurs on a system so that it may be cleared immediately.

Low-voltage ground detectors may be divided into two general classes.—Incandescent lamp detectors, Fig. 72, and voltmeter detectors, Fig. 73, *II*. Each of these types will be

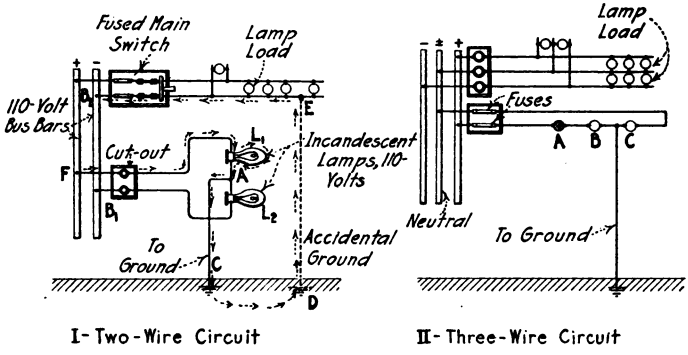


FIG. 72.—Lamp ground detectors for two- and three-wire circuits.

briefly discussed in the paragraphs which follow. For a more complete description see the author's AMERICAN ELECTRICIANS' HANDBOOK.

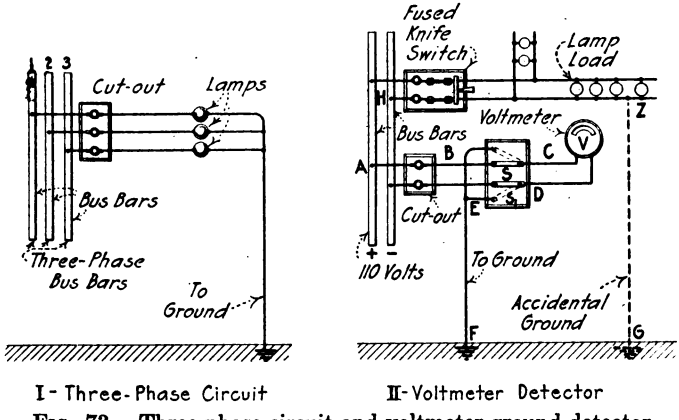


FIG. 73.—Three-phase circuit and voltmeter ground detector.

Ground detectors should, as a rule, remain continuously in circuit, because if they are so arranged that they may be cut in and out of circuit it is quite possible that one ground may

occur on the system and not be noticed until another ground occurs on a wire of opposite polarity, in which case a short-circuit, with the attendant dangers outlined above, might result. It is for these reasons that ground detectors employing incandescent lamps are, where their application is feasible, probably better than a voltmeter ground detector, because ordinarily the lamps can be so connected that they will remain continuously in service, whereas voltmeter ground detectors are usually so connected that they are switched in and out of circuit.

The principle of the incandescent lamp ground detector is illustrated in Fig. 72, *I*, which shows the connection for the simplest possible arrangement. Note that two lamps L_1 and L_2 are connected in series, through a cut-out, across the bus bars or across some portion of the distribution system which the ground detector is to protect. From point *A* between the two lamps, a permanent ground connection is made to *C*. Obviously since the two lamps, L_1 and L_2, are connected in series across the bus bars, current will be forced through them from *F* around to B_1 and the lamps will burn. If two 110-volt lamps are used in series as shown in the illustration, half the normal current will flow through them and hence both of the lamps will burn dimly.

EXAMPLE.—Assume that an accidental ground (Fig. 72) occurs at any point, *E*, on one of the negative wires of the wiring system with which the ground detector is associated. Then there is a conducting path from the positive bus bar to the negative bus bar, as shown by the dotted arrows, that is from *F* around to B_2, thus: FL_1ACDEB_2. Now, if the accidental ground, *ED*, is of reasonably low resistance, the effect is that the lamp L_1 is connected directly between the positive and the negative bus bars and hence will burn at practically full brilliancy. It should be noted that incandescent lamps have relatively high resistances. For example, a 16-c.p., 110-volt lamp has a resistance of about 220 ohms. Now the path *ACDE*, really constitutes a low-resistance shunt around the high-resistance lamp L_2 so that practically no current will flow through it and it will not give out light.

Hence with a ground on one of the negative wires of the wiring system, the ground lamp connected directly to the positive

bus bar will burn brightly and the lamp connected to the negative bus bar will go out. If a ground occurs on the positive side of the system the lamp connected directly to the negative side of the system will burn brightly and the other one will go out. If the accidental ground *ED* on the system is of high resistance, the lamp L_2 will not be extinguished entirely but may burn dimly at an intensity proportional to the resistance of the ground *ED*. The general principle thus outlined is the one upon which practically all types of lamp ground detectors depend for their operation.

Two-wire circuit lamp ground detectors can be arranged substantially as shown in Fig. 72, *I*, for either direct- or alternating-current circuits.

A three-wire circuit lamp ground detector is shown in Fig. 72, *II*. With the circuits arranged as shown, if a ground occurs on the negative leg of the system, all three lamps, *A*, *B* and *C*, will burn brightly. With a ground on the neutral conductor of the system, lamp *C* will be dark and *A* and *B* will burn dimly. With a ground on the positive leg of the system, *C* will burn brightly, but *A* and *B* will be dark. Lamp *A* may be mounted on the back of the switchboard or in some location where it is not visible, inasmuch as with only lamps *B* and *C* visible the attendant will be notified of grounds on the system. For a 125–150-volt three-wire system, use for *A*, *B* and *C* three 110-volt lamps. For a 250–500-volt three-wire system, use three 220-volt lamps.

A lamp ground detector for a three-phase system is shown in Fig. 73, *I*. The lamps are connected in star, one lamp between each of the phase conductors and ground. If a ground occurs on any phase-wire the lamp connected to that wire burns dimly and the other two lamps burn brightly.

Sensitiveness of Ground Detector Lamps.—In some laboratory tests of a two-lamp detector made with two ordinary 110-volt, 16-c.p. lamps, the sensitiveness indicated in the following table was found.

This shows that the lamp detector, while it will not indicate extremely small leaks, will show any leak that is likely to be dangerous from a fire standpoint.

Difference in brightness of lamps	Insulation resistance, ohms
Just noticeable in rather dark place	2,700
Easily detected	1,700
One lamp red, other bright	500

Sensitiveness of Ground Detector Lamps on a Three-wire Circuit.—This table shows the sensitiveness obtained in some laboratory tests, using ordinary 220-volt, 16-c.p. lamps.

Difference in brightness of lamps	Insulation resistance, ohms		
	Positive	Negative	Neutral
Just noticeable in rather dark place	18,800	8,900	3,700
Easily detected	9,000	6,500	2,600
One or two lamps dull red, others bright	3,800	3,300	500
One or two lamps faint red, others bright	2,400	1,400	0
One or two lamps just out, others bright	1,200	700	0

Voltmeter ground detector connections are shown for a two-wire circuit in Fig. 73, *II*. By changing the position of the blades of switch *S* the voltmeter may be connected across the bus bars of the system, thus indicating the station voltage, or it can be connected between either of the bus bars and ground. Assume, for example, that the voltage between the bus bars is 110, and that an accidental ground *ZG* occurs on the negative side of the system. Then with the lower switch lever in the dotted position S_1 and the upper switch lever in the position shown, the voltmeter will be connected by the accidental ground directly across the buses. Current would flow through the voltmeter by way of the route, $ABCVDS_1E$ $FGZH$. Therefore, if the resistance of the accidental connection *ZG* were very low, the voltmeter would read practically 110 volts. If the resistance of the accidental ground connection were high, the voltmeter would indicate a correspondingly low reading. Thus it is possible to estimate the resistance of an accidental ground from the reading of the voltmeter connected as shown.

EXAMPLE.—Assume a voltmeter which has a resistance of 10,000 ohms gives a reading of 100 volts when connected across a 100-volt circuit. Then if this same voltmeter gives a reading of 50 volts when connected in series with an accidental ground across a 100-volt source, it is evident that the total resistance in this circuit must be twice the resistance of the voltmeter itself, or 20,000 ohms. Obviously, then, the resistance of the ground is 10,000 ohms. Other values may be computed by using the method of proportion just indicated. A schedule can be tabulated from these computations indicating the resistance of a ground for certain scale deflections—say 5 volts apart—of the voltmeter.

A special ground-detecting voltmeter designed for continuous operation and arranged with a pointer moving on each side of a zero point, so that the presence of ground on either side of the system will be automatically indicated, can be obtained. Such a detector is the best instrument for all direct-current work where the voltage is too great for the application of any form of lamp detector, as, for instance, on series arc-light circuits. The special instrument is better than an ordinary voltmeter arranged as in Fig. 73 as it can be connected in circuit continually and hence is entirely automatic in its indications.

Ground Detectors for all Ordinary Low-voltage Single-phase Alternating-current Systems.—The lamp detectors above described may be used with good results.

Ground Detection on Alternating-current Systems where the Voltage is too High to Permit the Use of any of the Methods Previously Described.—Excellent results can be obtained where direct current is available by testing the line with a direct-current voltmeter, as in Fig. 73, *II*. This can be done only while the high voltage is cut off. If direct current is not available, the line may at frequent intervals be tested out with a powerful testing magneto when the voltage is off of the system. With extra-high-voltage circuits there is usually either no ground or else a fairly good one, so that either of these two methods may be used to advantage.

Commercial Ground Detectors for High-voltage Circuits.—There are instruments on the market especially designed for ground detection on high-voltage circuits. An example is the

electrostatic detector, in which the electrostatic repulsion between adjacent segments moves a pivoted vane, to which is attached an indicating needle traveling in front of a scale. There is also the "transformer-and-lamp" detector, in which a small transformer is used with an incandescent lamp in the secondary circuit. One of the primary wires is connected with the ground, and by means of switches suitably arranged the other primary may be connected to any wire of the system. A ground is indicated by the burning of the lamp. The indications of this instrument may be misleading, except to those thoroughly acquainted with its operation under all conditions.

The general directions which should be followed in installing lamp ground detectors are: A keyless lamp receptacle should be used. Switches should be omitted from the detector circuit. The detector lamp circuit should be protected with fuses. The ground lamps should be within an inch or so of each other so that differences in their brilliancies can be readily visible. See the author's AMERICAN ELECTRICIANS' HANDBOOK for further information.

Ground-detector ground wires should not be connected to gas pipes for the reason that there is always a possibility of a ground connection carrying a heavy current which might ignite the gas and cause a fire.

Continuously-indicating detectors are in some localities required for all circuits. For example, the FACTORY MUTUAL RULES specify that ground detectors of the continuously-indicating type will be required on all ungrounded systems for voltages below 250. For voltages greater than 250 continuously-indicating detectors which do not permanently ground the system (electrostatic ground detectors for example) are recommended and in some cases may be required. Electrostatic ground detectors can be obtained for operation on circuits of practically any commercial voltage. Obviously, lamp ground detectors are not applicable to circuits operating at voltages exceeding, say, 500. Voltmeter (non-continuously indicating) ground detectors are in many cases used for circuits operating at voltages above 500, but the electrostatic detector is obviously the safer and more desirable.

7b. ¶*I.* TESTING OF INSULATION RESISTANCE. Where continuously indicating detectors are not feasible, the circuits should be tested at least once per day, and preferably oftener.

The insulation resistance of a wiring system or a piece of electrical apparatus is the resistance between the conducting portion of the system or apparatus and the earth. Inasmuch as the metallic frames of electrical machines and devices are usually, after the apparatus is installed, in electrical contact with the earth, the insulation resistance of such a device is ordinarily taken as the resistance between the conducting portion of the device and the metallic frame.

Although the conductors in a wiring system are supported on so-called insulators and the windings of electrical machines are "insulated" from the metallic frames thereof, it should be remembered that there is no such thing as a perfect insulator, and that all substances are electrical conductors to some extent. Substances that are called insulators are such poor electrical conductors that practically no current flows through them. Although the resistance of the so-called insulators is extremely high, it can be measured quite readily as can the insulation resistance of a wiring system, or of a piece of apparatus. If the insulation resistance of a wiring system to ground is very low, the system is said to be "grounded." If the resistance of the insulation of an electrical machine between conducting portions of the windings and the metallic frame is low, the winding is said to be grounded. Hence the term "low insulation resistance" implies a heavy ground on the system or apparatus in question.

The Instruments for Measuring Insulation Resistance are Many.—Certain special types such as the Ohmmeter and the Megger, similar to those described in the AMERICAN ELECTRICIANS' HANDBOOK but which cannot be described here, are frequently used. The Wheatstone bridge is often applied in this work, as described in the AMERICAN ELECTRICIANS' HANDBOOK. For many cases in practical work the most convenient instrument is an ordinary voltmeter which can be readily utilized as shown in Figs. 74, 75, 76 and 77.

The theory of the voltmeter method of measuring insulation resistance is as follows: When the same current flows through

each of two conductors in series, the volts drop across each of the conductors will be proportional to the resistance of that conductor. Then, with an unknown resistance R_x (Fig. 74) connected in series with a voltmeter across the source of e.m.f. as shown, the volts drop across R_x will be proportional to its (unknown) resistance. Furthermore, the volts drop, V_v, across the resistance of the voltmeter as indicated by the reading of the voltmeter itself will be proportional to the resistance of the voltmeter. It follows then that a proportion can be written, thus:

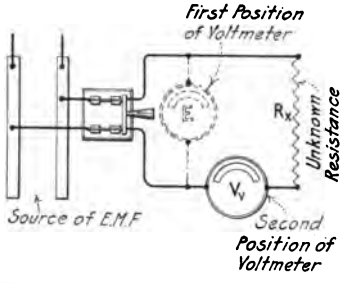


FIG. 74.—Illustrating method of measuring insulation resistance.

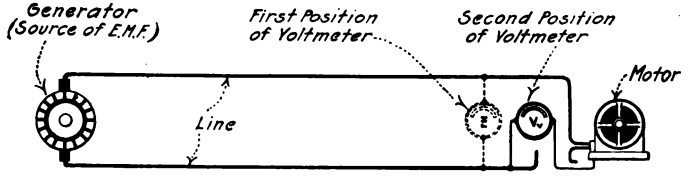


FIG. 75.—Testing the insulation resistance of a motor or generator from its winding to ground.

$$\frac{V_v}{V_x} = \frac{R_v}{R_x} \tag{1}$$

Then, solving for R_x, the unknown resistance, the following formula results:

$$R_x = \frac{R_v \times V_x}{V_v} \quad \text{(ohms)} \tag{2}$$

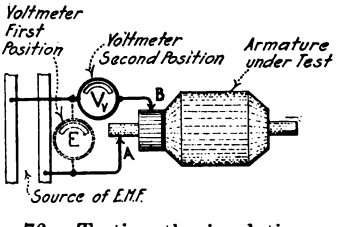


FIG. 76.—Testing the insulation resistance of an armature.

Wherein, V_v = the volts drop across the voltmeter as indicated by the instrument itself. V_x = the drop in volts across the unknown resistance. R_v = the resistance of the voltmeter in ohms. R_x = the resistance of the unknown resistance in ohms.

In equation (2) R_x is unknown, it being the value sought. The resistance R_v of the voltmeter V_v can be read from the instrument and is therefore known. Now V_x can be ascertained by subtracting from the e.m.f., E (impressed across the voltmeter and the unknown resistance in series), the voltage drop across the voltmeter (see Fig. 74). Obviously, the difference between E and the voltage drop across V_v must be the voltage drop across R_x. Then it may be stated that

$$V_x = E - V_v \qquad \text{(volts)} \tag{3}$$

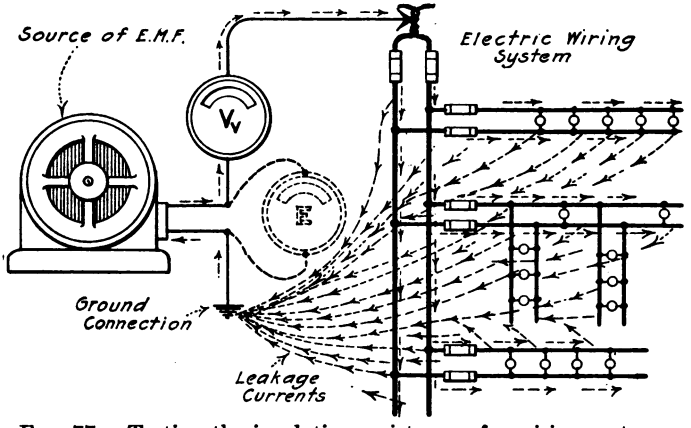


FIG. 77.—Testing the insulation resistance of a wiring system.

Then substituting this value of (3) for the V_x in (2) the resulting formula is

$$R_x = \frac{R_v \times (E - V_v)}{V_v} \qquad \text{(ohms)} \tag{4}$$

Wherein (Fig. 74), V_v, R_v and R_x have the same meanings indicated above, and E = the e.m.f., or voltage, impressed across the voltmeter and unknown resistance connected in series across a source of e.m.f. as shown. The above is the working formula used in measuring high resistance with a voltmeter. Its application is illustrated below.

The procedure in measuring a high resistance with a voltmeter is: *First,* measure the voltage or e.m.f., E, Fig. 74, available for the test. The source of this e.m.f. may be any

that will remain reasonably constant while the test is being made and that will give a practically full-scale deflection of the voltmeter used. A direct-current generator, a storage battery or, in certain cases, a primary battery, can be used. *Second*, a voltmeter (it may be the same one that was used for measuring E) the resistance of which is known, is connected, as shown in Fig. 74, in series with the unknown resistance, across the e.m.f., E, and the reading, V_v, which the instrument then gives is noted. Knowing the values of E, the impressed e.m.f., V_v, the voltage drop across the voltmeter, and R_v, the resistance of the voltmeter, these values may be substituted in formula (4) and the unknown resistance computed. It is not necessary to use the same voltmeter for taking the reading E and the reading V_v although it is desirable to do so. A high-reading instrument can be used for ascertaining the voltage of the e.m.f. source and a millivoltmeter for the determination of the V_v value. Where the insulation resistance is very high the deflection with the voltmeter at V_v may be so small that it cannot be detected.

EXAMPLE.—With the apparatus connected as shown in Fig. 74, using a direct-current lighting circuit as a source of e.m.f., the readings were as follows: The voltmeter when connected as at E to measure the impressed e.m.f. read 105 volts. When connected as at V_v in series with the unknown resistance it reads 3.2. The resistance of the voltmeter as ascertained from its manufacturer was 20,000 ohms. What was the resistance in ohms of the unknown resistance?

SOLUTION.—Substitute in formula (4):

$$R_x = \frac{R_v \times (E - V_v)}{V_v} = \frac{20{,}000 \times (105 - 3.2)}{3.2} = \frac{20{,}000 \times 101.8}{3.2} = 636{,}250 \text{ ohms.}$$

Armature insulation resistance may be measured with a voltmeter as suggested in Fig. 76. In taking these readings the voltmeter is first connected across the source of e.m.f. and is then connected in series as shown. One of the leads to the armature, A, is connected to the shaft, while the other, B, is connected to one or all of the commutator bars of the

armature. That is, the voltmeter V_v is connected in series across the source of e.m.f. in a circuit comprising (1) the voltmeter itself, (2) the conductors of the armature, (3) the insulation of the armature from its shaft and (4) the shaft of the armature. The insulation resistance of the armature and that of the voltmeter are so great as compared with the resistances of the other components of this circuit, that the resistances of these other components may be disregarded.

EXAMPLE.—In measuring the insulation resistance of an armature as shown in Fig. 76, a voltmeter having a resistance of 10,000 ohms was used. The voltage of the source of e.m.f., E, was 108. With the voltmeter connected in series, it read 0.8 volt. What was the insulation resistance of the armature?

SOLUTION.—Substitute in formula (4):

$$R_x = \frac{R_v \times (E - V_v)}{V_v} = \frac{10{,}000 \times (108 - 0.8)}{0.8} = \frac{10{,}000 \times 107.2}{0.8} = 1{,}340{,}000 \text{ ohms.}$$

The method of measuring the insulation resistance of the stator windings of an electrical machine with a voltmeter is illustrated in Fig. 75. The procedure is much the same as that described in connection with Fig. 76 illustrating the measurement of the insulation resistance of an armature. One lead from the source e.m.f. connects to the conducting portion of the stator windings of the machine while the other lead from the source is connected, but through the voltmeter, to the frame of the machine, thus placing the voltmeter, V_v, in series with the insulation resistance across the source of e.m.f.

The measurement of the insulation resistance of a wiring system can be made as shown in Fig. 77. The voltmeter is first connected across the terminals of the source of e.m.f. (in the case shown a generator is used) and the reading E is obtained. Then one terminal of the source of e.m.f. is grounded and the other is connected through the voltmeter to the electric wiring system. The almost infinitesimal leakage currents impelled by the source of e.m.f. would flow through the wiring system to ground through the source of

e.m.f. and through the voltmeter, V_v, somewhat as indicated diagrammatically in Fig. 77. As noted in *Rule* 88 the insulation resistance of wiring systems must be very high. No difficulty whatever is encountered in satisfying the requirements of this *Rule* 88 if the CODE instructions relating to construction are followed.

EXAMPLE.—A voltmeter having a resistance of 2,200 ohms is used to measure the insulation resistance of a wiring system as shown in Fig. 77. The source of e.m.f., E, impresses a voltage, as shown by the reading of the instrument, of 115 volts. When connected in series with the wiring system and ground, the voltmeter V_v read 0.5 volt. What was the resistance of the system?

SOLUTION.—Substitute in formula (4):

$$R_x = \frac{R_v \times (E - V_v)}{V_v} = \frac{2{,}200 \times (115 - 0.5)}{0.5} = \frac{2{,}200 \times 114.5}{0.5} = 503{,}800 \text{ ohms.}$$

8. MOTORS.

8*a*. ¶*I*. MOTORS. Must, when operating at a potential in excess of 550 volts, have no exposed live metal parts, and have their base frames permanently and effectively grounded.

The frames of all motors should be grounded (this applies particularly to high-voltage motors) that is, connected to the earth by low-resistance substantial conductors, to minimize fire and life hazard. Motor frames should be grounded for the same reasons that dictate the grounding of generator frames as discussed under *Rule* 1*c*. If the motor operates at a pressure below 550 volts it is desirable though not imperative that its frame be grounded.

One method of grounding a motor which is installed inverted at the ceiling of an industrial plant is shown in Fig. 78, which shows a ground connection between the motor frame and a sprinkler pipe. In factory buildings sprinkler pipes are usually available and provide excellent opportunities for securing good grounds. The ground wire of Fig. 78 is connected to the sprinkler pipe with an approved ground clamp and to the motor-base frame by clamping it between two washers

under the head of a bolt as shown in Fig. 8. It should be noted, however, that in a building where an automatic, electrically-operated, sprinkler-alarm system is in use, the grounding of motors or other devices on the sprinkler pipes is not usually permitted by the local inspection bureaus.

Sprinkler Pipe Sizes Should be Considered When Grounding Motors on Them.—The frame of a very large motor should not be grounded on a very small sprinkler pipe. It is probably permissible to ground a 10- or 15-h.p. motor to a ¾-in. branch pipe of a sprinkler system, but a 50-h.p. motor should be grounded to one of at least 2-in. nominal diameter. The pipe selected should in every case be of such size that there would be no possibility of its overheating when carrying the current which the fuses protecting the motor will safely pass. Obviously if the current through the motor-frame and ground wire and sprinkler system becomes greater than that which the motor fuses will pass, the fuses will melt and open the circuit.

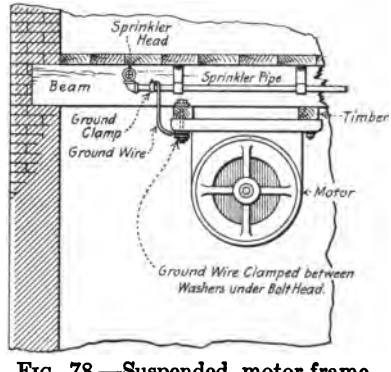


FIG. 78.—Suspended motor-frame grounded on a sprinkler pipe.

Methods of effecting earth connections for motor-frame grounding are similar to those which are described under *Rule* 1*c*, used for grounding generator frames. Various methods of making earth connections are described in detail under *Rule* 15*g*.

8*a*. ¶*II*. MOTORS. Must, when operating at a potential of 550 volts or less, have their base frames permanently and effectively grounded wherever feasible. Where grounding of the frame is impracticable, special permission for its omission may be given in writing, in which case the frame must be permanently and effectively insulated. Wooden base frames used for this purpose and wooden floors which are depended upon for insulation where for any reason it is necessary to omit the base frames must be kept filled to prevent absorption of moisture and must be kept clean and dry.

Where frame grounding is impracticable, and the motor operates at a pressure lower than 550 volts, the frame should be thoroughly insulated from the earth. In this respect the practice is the same with generators (*Rule* 1c, ¶*II*) as with motors. The motor frame should be either effectively connected to the earth or thoroughly insulated from it. Motor frames may, where necessary, be insulated from the earth by the same methods as those discussed under *Rule* 1c, ¶*II*, which are used for insulating generator frames.

8b. ¶*I*. MOTORS. Motors operating at a potential of 550 volts or less must be wired with the same precautions as required by rules in Class "C" for wires carrying a current of the same volume.

The wiring for motors should, in general, be installed in accordance with the same general rules that apply to all inside wiring (that is, Class *C* wiring) for electric lighting or other purposes.

8b. ¶*II*. MOTORS. Motors operating at a potential between 550 and 3,500 volts must, except in central or sub-stations, be wired with approved multiple-conductor, metal-sheathed cable in approved metal conduit. All apparatus and wiring connected to the high-tension circuit must be completely enclosed in substantial grounded metal shields or casings and the conduit must enter and be properly secured to such casings or to suitable terminal boxes screwed or bolted to the casings.

The wiring for 550-3,500-volt motors should be done with multiple-conductor (that is, duplex or triplex) lead-sheathed

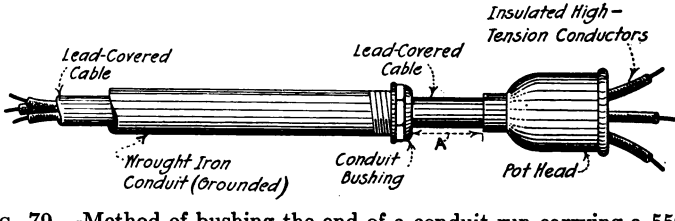


FIG. 79.—Method of bushing the end of a conduit run carrying a 550 to 3,500-volt lead-covered cable.

cable, carried in metallic conduit. When this conduit is grounded, the possibility of the high voltage imposed on the conductors creating a fire or increasing life hazard is much decreased for essentially the same reasons that grounding

generator and motor frames and transformer secondaries decreases fire and life hazard. Grounded metal sheaths should be used for encasing all high-tension apparatus for the same reasons. Approved bushings (Fig. 79) are used at the ends of such conduits because it obviously would be impracticable to carry the lead cable through the approved outlet fittings of the types which are required at all conduit terminations in ordinary low-voltage conduit wiring.

A high-tension cable-conduit-outlet is shown in Fig. 79, which indicates the preferable method of terminating a conduit run which carries a high-tension lead-covered cable. To satisfy CODE requirements, it is merely necessary to screw a standard conduit bushing on the end of the conduit so that the lead sheath of the cable will be protected from abrasion. However, it is probable that where the portion, *A* (Fig. 79), of the sheath of the lead-covered cable is not protected by the iron conduit and is subject to mechanical injury, a metal sleeve extending from the conduit bushing to the cable pothead should be installed. Such a sleeve, which might be made of cast or sheet iron, brass or copper, can be made in two pieces and secured in place with a band.

8*b*. ¶*III*. MOTORS. The insulation of the several conductors for high potential motors, where leaving the metal sheath of cables, must be thoroughly protected from moisture and mechanical injury. This may be accomplished by means of a pot head or some equivalent method. The conduit must be substantially bonded to the metal casings of all fittings and apparatus connected to the inside high tension circuit.

Potheads should be provided at the ends of high-tension motor cables to prevent injury to and to separate the conductors. There is always danger of moisture entering the cable or of the insulation of the conductor becoming cracked at the point where it leaves the cable unless a pothead (Figs. 37 and 79) is provided. All conduits and metal protective casings of the high-tension installation should be electrically interconnected—connected together—so that there can be no difference of potential between the parts and so that all protective metal parts will be connected to ground. All conduit should always (*Rule* 28*f*, ¶*I*,) be grounded.

8b. ¶*IV*. MOTORS. Where outside conductors directly enter the motor room special permission in writing must be obtained to install the wires for high potential motors according to the general rules for high potential systems.

8b. ¶*V*. MOTORS. Conductors carrying the current of only one motor must be designed to carry a current at least 25 per cent. greater than that for which the motor is rated. Where the conductors under this rule would be overfused in order to provide for the starting current, as in the case of many of the alternating current motors, the conductors must be of such size as to be properly protected by these larger fuses.

The wires constituting the branch circuit serving one direct-current motor must be at least large enough that they will carry (in accordance with *Rule* 18) 1.25 times the full-load current of the motor. For example, Fig. 80 shows a set of branch conductors *AB* carrying the current to one direct-current motor. Assume that the current taken by this motor

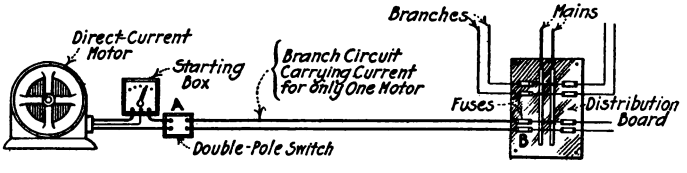


FIG. 80.—Protection for tap serving one direct-current motor.

at full load as indicated by the name plate on its frame, or by computation, is 20 amp. Then the wires composing the tap *AB* must be capable of carrying at least $20 \times 1.25 = 25$ amp. Then (referring to *Table A* of *Rule* 18) a wire at least as large as No. 10 would have to be used if rubber-insulated conductor is to be utilized, or it would have to be as large as No. 12 if other insulation than rubber (*Rule* 18, *Table B*), such as weatherproof or slow-burning, is to be used. If the branch *AB* were quite long, it might be necessary to use wires considerably larger than those just specified, in order to maintain the voltage drop within reasonable limits, but No. 10 or No. 12, respectively, would be safe from a current-carrying standpoint and are the smallest wires that should be used. The conductors must always be of such size that the fuses (*B*) through which the current feeds to them will protect them

in accordance with the requirements of *Rule* 18, and in no case should the main fuses at *D* (Fig. 81) be smaller than the fuses protecting the branch circuit to the motor.

Where a number of direct-current motors tap from a main (as at Fig. 81 where the main is represented by *CD*) the wires composing each branch carrying the current of only one motor, as *E*, *F* and *G*, must be large enough to carry (in accordance with *Rule* 18) a current 25 per cent. greater than the full-load current of the motor. The wires used for mains *CD* may be of any reasonable size, provided the fuses at *D* which protect them are of such capacity that the wires *CD* cannot carry a greater current than is allowable under *Rule* 18.

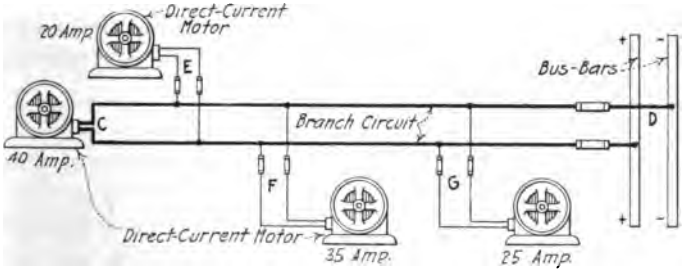


FIG. 81.—Arrangement of protection for a main serving a group of direct-current motors. (Starting boxes and switches omitted for simplicity.)

The usual method of determining a wire size for a direct-current motor main like that of *CD*, which supplies several motors, is to add together the full-load currents of all of the motors and then assume that the current in the main *CD* will never exceed from possibly 60 per cent. to 75 per cent. of this total.

EXAMPLE.—If the full-load currents of the motors of Fig. 81 were, respectively, 20, 40, 35 and 25 amp. the current in the main *CD* would be, if all of the motors were operating at full load at the same time, 120 amp. Experience has shown that it is seldom that all of the motors of a group will simultaneously draw their full-load currents. It is therefore allowable to use a "demand factor." The demand factor of an installation is the ratio of the maximum load which the installation imposes

on the supply system, to the total connected load of the installation. Assume a demand factor of 75 per cent.; then the main *CD* should be proportioned to carry $0.75 \times 120 = 90$ amp., that is, with rubber insulated wire (see *Table* of *Rule* 18), No. 2 should be used, and with other insulation No. 4. The fuses at *D* should have a capacity of 90 amp. In any case, the conductors must be of such size that the fuses through which the current feeds to them will protect them in accordance with the requirements of *Rule* 18. In no event should the capacity of the fuses *D* which protect the main be smaller than the fuses protecting the branch circuit to any one motor.

The minimum permissible conductor size for a branch for one alternating-current motor may be determined as will be outlined. Practically all alternating-current motors have the characteristic of drawing much greater current (possibly two to five times greater), at the instant when they are first connected

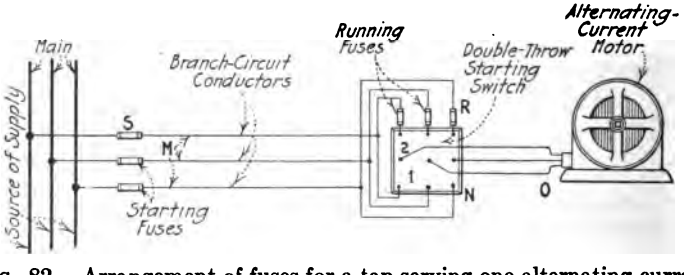


FIG. 82.—Arrangement of fuses for a tap serving one alternating-current motor.

to the line than they draw after their rotors have attained full speed. Because of this fact special precautions should be taken in wiring alternating-current motors. Usually, for all except the smallest alternating-current motors, two sets of fuses, Fig. 82, are used. The starting fuses, *S*, must be of sufficient capacity to pass the starting current taken by the motor. If this starting current continued to flow for any considerable length of time in the motor windings, it would "burn them out;" hence the starting fuses of themselves do not provide adequate protection for the motor. To protect the motor against excessive currents, after it has attained speed, running fuses, *R* (Fig. 82), are inserted in the circuit.

Alternating-current motors are usually started by using a double-throw switch. Fig. 82 with unessential details omitted, shows the arrangement. The starting switch is first thrown to *starting position* 1 and current is forced through the motor, which starts it, only the starting fuses being in series between the source of e.m.f. and the motor. After the rotor has attained normal speed the current taken by it is greatly decreased and the starting switch is thrown to the *running position*, 2. Then both the starting fuses and the running fuses are in the circuit. The running fuses ordinarily have a capacity such that they will pass a current 25 per cent. greater than the full-load current of the motor. All motors will carry a 25 per cent. overload for a considerable period. The starting fuses on the other hand frequently have capacities such that they will pass 200 per cent. or more of the full-load current of the motor.

In selecting the wire size for a branch circuit for one alternating-current motor, the starting current taken by the motor under the specific conditions of operation to which it will be subjected should be ascertained from the manufacturer, or by test. The starting fuses *S* must be selected of such capacity that they will pass this starting current. Then the branch-circuit wires, *M*, *N*, *O*, must be selected of such size that they will be protected (in accordance with the requirements of *Rule* 18), by the starting fuses *S*.

NOTE that (*Rule* 8c, ¶*V*) rubber-covered conductor branch circuits to alternating-current motors may be protected in accordance with the safe current values of *Table B*—insulations other than rubber—unless time-limit circuit-breakers constitute the overload protection. It should be particularly recognized that this concession in current-carrying capacity allowed under *Rule* 8c, ¶*V*, applies only in the case of a branch circuit feeding *one alternating-current motor requiring large starting current.* Study the *following* example.

EXAMPLE.—Consider a motor that has a full-load running current of 20 amp., and a starting current of 40 amp. At *S* (Fig. 82) 40-amp. fuses would be used. With "rubber insulation" or with "other insulations" No. 8 wire (*Rule* 18, *Table B*) would be used for branch, *M*, *N*, *O*. The running fuses should be capable of passing a current about 25 per cent.

in excess of the full-load running current of the motor or: 20 *amp.* × 1.25 = 25 *amp.* Hence, the running fuses, *R*, should be 25-amp. fuses. Note that starting compensators, or auto-transformers (not shown in the illustration), are extensively used for alternating-current motor starting equipments to minimize the starting current. The inclusion of such equipment in the circuit would not alter the principles outlined.

The determination of the smallest wire permissible for an alternating-current main serving several motors is made by practically the same method as that used in determining the permissible wire size for a direct-current motor main as described above except that a greater demand factor should be used. The maximum current that will normally flow in an

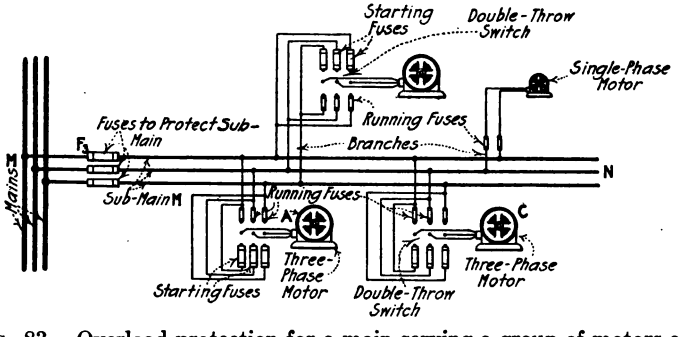


FIG. 83.—Overload protection for a main serving a group of motors and for the motors.

alternating-current motor main as *MN*, Fig. 83, will probably in the average case be equal to from 45 per cent. to 85 per cent. of the sum of the full-load currents of all of the motors, that is, the demand factor will range somewhere between 0.45 and 0.85. Where specific information is not available, a demand factor of 0.80 may be used. Hence fuses, F_3, should be selected of such capacity that they will pass the maximum line current thus determined, and the wires constituting the main *MN* must be of such size that these fuses will protect them in accordance with the requirements of *Rule* 18. However, if it is found that the current in *MN* is greater than was anticipated and it is necessary to increase the sizes of the fuses F_3

to enable them to pass the normal running current in the main new and large conductors for *MN* must be selected of such size that the new fuses will protect them. In no case should the fuses at *F* be smaller than the starting fuses protecting any one of the motors. The conductor and fuse sizes for the branch circuit to each motor may be determined by the method described in the preceding paragraph.

8b. ¶*VI.* MOTORS. The current used in determining the size of the conductor carrying the current of only one varying (or variable) speed motor must be the percentage of the 30-minute current rating of the motor as given for the several classifications of service in the following table:

Classification of service	Percentage of current rating of motor
Operating valves, raising or lowering rolls	200
Rolling tables	180
Hoists, rolls, ore and coal handling machines	150
Freight and passenger elevators, shop cranes, tool heads, pumps, etc	120

In determining wire sizes for taps or branches for varying-speed motors the fact that the current taken by the motors is subject to extremes of variation must be considered. It is seldom, in practice, that the current of a varying-speed motor is constant. The nature of the loads and the characteristics of the motors are such that the power output of the motor and the current input may be zero at one instant and a maximum a short interval later. Hence it is undesirable to rate these motors on the basis of the horse-power output they will deliver continuously. Instead, they are usually rated on the basis of their output for 30 min. Obviously a motor will have a greater power output on the basis of its 30-min. rating than it will on the basis of a continuous rating because the power that any electrical machine can deliver is determined to a considerable extent by the heating of the machine. The temperature at no part of the machine should ever exceed a certain maximum, usually 100°C., or 212°F. It is apparent that the machine can carry a greater load for 30 min. without its

temperature exceeding 100°C. than it can carry continuously without its temperature exceeding 100°C. It is for these reasons that constants must be used in determining the wire size for varying-speed motor leads.

EXAMPLE.—Consider the case of Fig. 84, where the rolling-mill motor, on the basis of a 30-min. rating, takes, 100 amp. Then leads *LD* would have to be of such size that they would safely carry at least 100 amp. × 1.50 = 150 amp., where "1.50" (150 per cent.) is the constant as taken from Table 8*b* ¶*VI*.

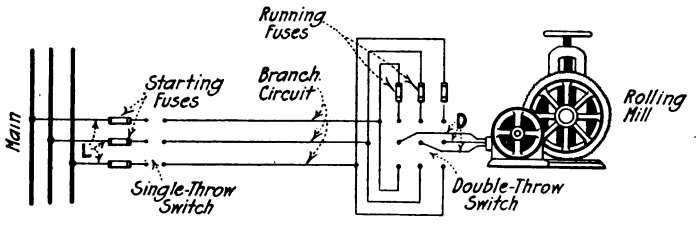


FIG. 84.—Overload protection for conductors serving one alternating-current motor driving a roll.

8*b*. ¶*VI*. NOTE.—MOTORS. Varying speed motors are motors in which the speed varies automatically with the load, decreasing when the load increases, and vice versa. It does not mean motors in which the speed is varied by the use of different windings or grouping of windings, or motors in which the speed is varied by external means, and in which, after adjusting to a certain speed, the speed remains practically constant.

8*c*. ¶*I*. MOTORS. Each motor with its starting device must be protected by a cut-out and controlled by a switch (see No. 19 *a*), said switch plainly indicating whether "on" or "off" (except as provided for electric cranes, see No. 43 *c*). Small motors may be grouped under the protection of a single set of fuses, provided the rated capacity of the fuses does not exceed 10 amperes and the total wattage of the circuit does not exceed 660. With motors of one-fourth horse power or less, on circuits where the voltage does not exceed 300, single pole switches may be used as allowed in No. 24 *c*. The switch and rheostat must be located within sight of the motor, except in cases where special permission to locate them elsewhere is given, in writing.

The protective and starting devices in the branch circuit to a motor are shown in Fig. 85. In the illustration a circuit-breaker is shown in lieu of fuses, circuit-breakers being acceptable under certain restrictions as indicated below. They are preferable to fuses in certain cases.

Switches indicating whether they are on or off are procurable in several types. A knife switch which is exposed to

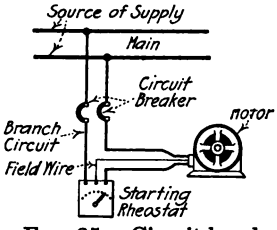


FIG. 85.—Circuit breaker providing overload protection and constituting circuit-opening device in motor installation.

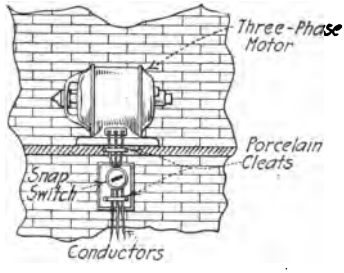


FIG. 86.—Small motor controlled by enclosed snap switch.

view obviously indicates whether the circuit it controls is closed or open and indicating snap or flush switches, Figs. 86 and 87 give the same information.

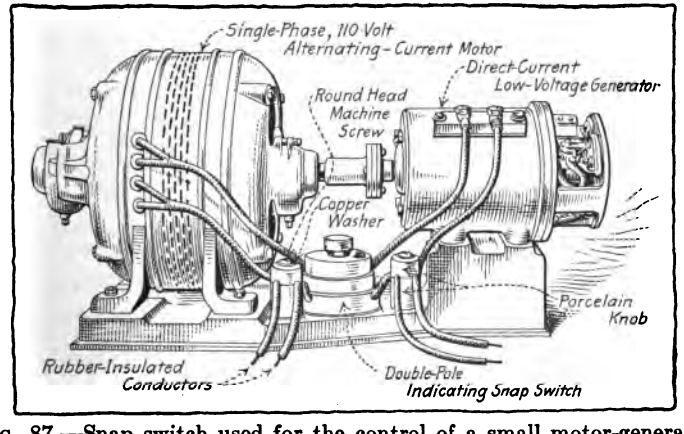


FIG. 87.—Snap switch used for the control of a small motor-generator set.

The illustration shows a Wagner Electric Co. battery charging motor-generator. The motor input and the generator output is less than 660 watts hence a double-pole snap switch is used, one pole cut in the generator circuit and the other pole in the motor circuit. Connected in this manner the one double-pole switch is equivalent to two single-pole switches.

A group of small motors may be protected by a single set of fuses, where the total load does not exceed that (660 watts)

ordinarily allowed on an incandescent lighting circuit. Fig. 88 shows a group of small motors so protected, the entire group

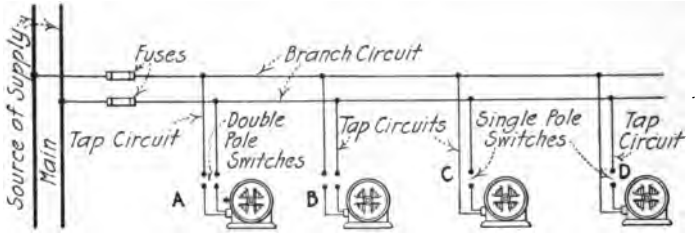


FIG. 88.—Group of small motors protected with a single set of fuses.

being fed through one set of fuses. Note that a small motor, where its output does not exceed ¼ h.p. and where the voltage does not exceed 300, may be controlled either by a

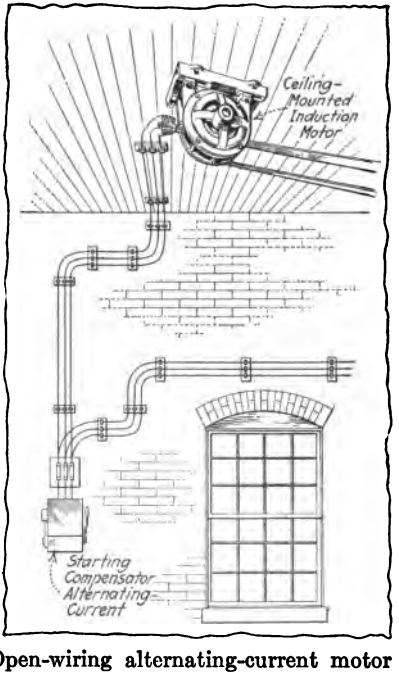


FIG. 89.—Open-wiring alternating-current motor installation.

double-pole switch as shown at *A* and *B* or by a single-pole switch as shown at *C* and *D*.

The switch and rheostat should be located within sight of the motor so that the operator in starting or stopping the motor will observe the motor's performance when he operates the switch or starting device. Furthermore, they should be located so that if any difficulty with the motor occurs it can be

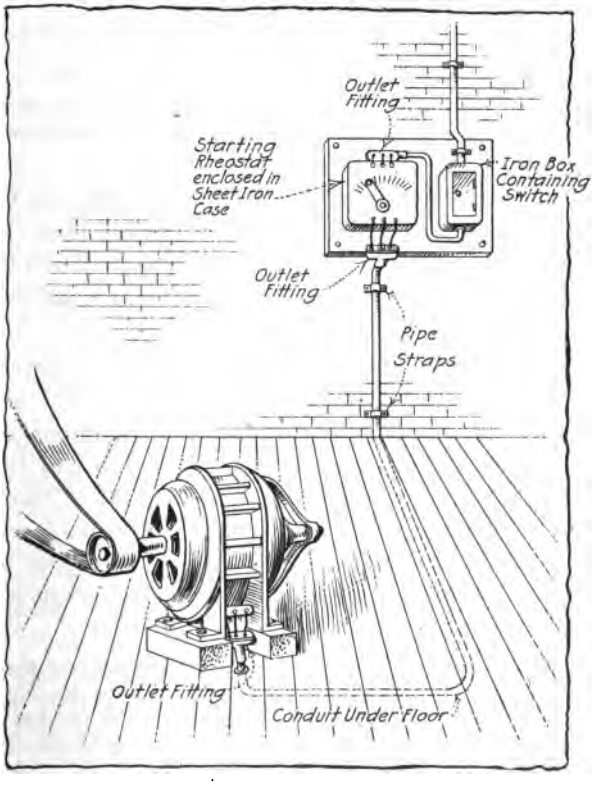


FIG. 90.—Motor wiring installed in conduit.

readily stopped. Fig. 89 shows an open-wiring installation for an alternating-current motor arranged in accordance with this requirement, while Fig. 90 shows a similar installation for a direct-current motor where the wiring is in conduit.

8c. ¶*II.* MOTORS. Where the circuit-breaking device on the motor-starting device disconnects all wires of the circuit, the switch called for in this section may be omitted.

Circuit-breaking devices disconnecting all wires of the motor circuit are frequently incorporated in control equipments. These devices perform all of the functions of a switch and hence may be used in lieu thereof. A main switch which disconnects all wires should be used for all elevator-motor control installations. A main switch is not usually required where an oil-switch starter is used for the control of an alternating-current motor.

8c. ¶*III.* MOTORS. Overload-release devices on motor-starting devices will not be considered to take the place of the cut-out required by this section.

Overload release devices on starting rheostats (see Fig. 56) do not provide adequate overload protection because they are frequently of frail construction and in any case do not provide protection to the portion of the motor branch circuit between the starting device and the main.

8c. ¶*IV.* MOTORS. An automatic circuit-breaker disconnecting all wires of the circuit may serve as both switch and cut-out.

Automatic circuit-breakers perform the functions of both fuses and switch where the breaker (Figs. 185 and 186) disconnects all of the wires in a circuit, as in Fig. 85. This means that if a circuit-breaker is to be substituted for *the fuses and a switch* in a two-wire motor circuit that a two-pole breaker must be used, or on a three-wire three-phase circuit a three-pole breaker should be installed.

8c. ¶*V.* MOTORS. Where a rubber-covered conductor carries the current of only one A. C. motor of a type requiring large starting current it may be protected by a fuse or an automatic circuit breaker without time limit device, rated in accordance with Table B of No. 18. The rated continuous current capacity of a time limit circuit breaker protecting a motor of the above type need not be greater than 125 % of the motor current rating, providing the time limit device is capable of preventing the breaker opening during the starting period.

Rubber-covered conductors serving alternating-current motors may be rated as to current-carrying capacity in accordance with the currents allowable for insulations other than rubber (*Rule* 18, *Table B*). The reason for this is that the starting current for such motors is much greater than the run-

ning current. But inasmuch as, under normal conditions, the starting current flows for only a short period there is no danger of overheating the conductor and thus damaging its insulation, even if a liberal current-carrying capacity rating is allowed.

EXAMPLE.—Assume (Fig. 82) that the branch circuit to the motor is to be of rubber-insulated wire and that the starting current taken by the motor is 100 amp. Ordinarily (*Rule* 18) No. 1 rubber-covered wire should be used to carry 100 amp. but in the case of the branch to *one alternating-current* motor, No. 3 rubber-covered wire could be used because No. 3 wire with insulations other than rubber will (*Rule* 18, *Table B*) safely carry 100 amp. Another example illustrating this condition is given under *Rule* 8*b*, ¶ *V*.

Time-limit devices are arrangements whereby a circuit-breaker is prevented from opening on a sudden overload, but which permit the breaker to open if the overload is continued. Fig. 91 illustrates the principle of one type. With the breaker closed, the current enters at *A*, passes through the solenoid *B* and continues via course *CDFGH*. When current flows the solenoid *B* is energized. When a current smaller than that for which the breaker is set at *S*, flows through the breaker, the attraction of the solenoid is not sufficient to lift disk *R* and iron plunger, or core, *P* and draw it up into the solenoid. However, if the current becomes greater than that for which the breaker is set, the magnetic attraction then overcomes these restraining effects and the tendency is to pull the plunger up into the solenoid until it strikes the trigger *T* which will release arm *D*. Then the spring *Q* will force the arm out to the position shown in dotted lines, opening the circuit.

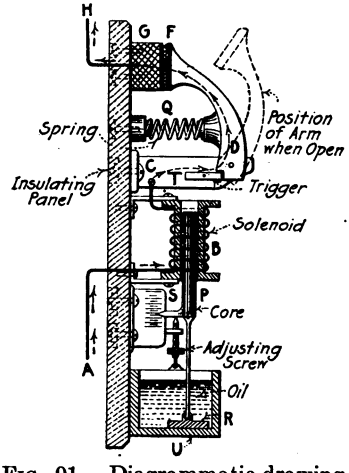


FIG. 91.—Diagrammatic drawing of a time-limit circuit breaker.

However, with the time-limit circuit-breaker the plunger is prevented from rising immediately because of the restraining action of the time-limit device (*U* and *R*) due to the cohesion of the smooth bottom of the disk *R* to the bottom of the cup *U*, which contains oil. But, if the overload endures the continued pull exerted by the solenoid on the plunger will overcome the cohesion between the disk and the bottom of the cup and it will then permit the plunger to rise and the circuit-breaker will be opened. Note then, that although the breaker of the type diagrammed in Fig. 91 will open under an overload that lasts for several seconds it will not open under a momentary overload.

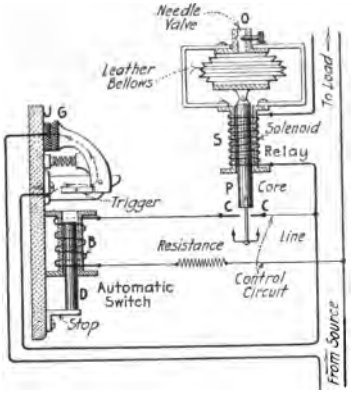


FIG. 92.—Diagram illustrating one type of time-limit relay.

Figure 92 illustrates the principle of a time-limit circuit-breaker of another type. With this device, the main current or a certain definite portion thereof circulates around the solenoid *S*. If this current becomes greater than that for which the instrument is set, the plunger *P* of the solenoid tends to rise. It is, however, restrained from rising abruptly by the bellows which must force the air it contains out of its air chamber through the small orifice *O* before the plunger can be raised any great distance. However, if the pull on the plunger due to the solenoid *S* is continued, the air will be forced out of the bellows, the plunger will rise, and the contactor *CC* will close the auxiliary circuit permitting current to circulate around the solenoid *B*. Then the plunger *D* will be attracted and the breaker will be tripped, opening the main circuit at jaws *J* and *G*. Figs. 91 and 92 are merely diagrams to illustrate the principles involved in the operation of these devices and are not intended to show their actual construction or proportions.

8c. ¶V. NOTE.—MOTORS. In the great majority of cases where A. C. motors of the above type are started by means of autostarters the current-carrying capacity of wires meeting the rule will not exceed the following percentages of the full load currents of the motors.

Rated full load current	Percentage
0– 30 amperes	250
31–100 "	200
Above 100 "	150

8d. ¶I. MOTORS. Rheostats must be so installed as to comply with *all* the requirements of No. 4. Auto starters must comply with requirements of No. 4 *c*.

Starting panels for direct-current motors are shown in Fig. 93. On these panels is mounted all of the equipment required for protection and starting of the direct-current motors. Panels such as these provide neat installations because they

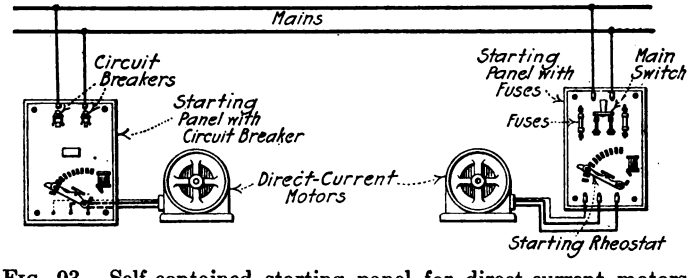


FIG. 93.—Self-contained starting panel for direct-current motors.

eliminate the necessity of wiring between protective devices, switches and rheostats. They are very simply installed, inasmuch as where they are used it is only necessary to carry two conductors to the line side of the starting panel and to run three conductors from the motor side of the starting panel to the motor.

8d. ¶II. MOTORS. Auto starters, unless equipped with tight casings enclosing all current-carrying parts, in all wet, dusty or linty places, must be enclosed in approved cut-out boxes or cabinets. Where there is any liability of short circuits across their exposed live parts being caused by accidental contacts, a railing must be erected around them.

Most auto starters are now provided with casings which enclose all current-carrying parts. In some makes of auto starters the cut-out arranged to receive the fuses has bare current-carrying parts, and in such instances this cut-out can be enclosed in a metal cabinet.

Railings should be provided around motors where there is any possibility of accidental contact with either the bare current-carrying parts of the motor or its starting device. A typical installation thus provided with a railing is shown in Fig. 94.

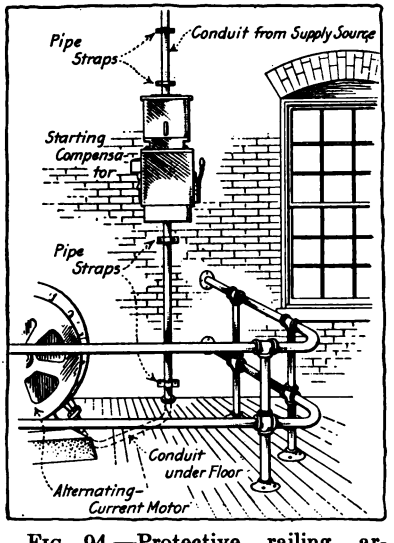


FIG. 94.—Protective railing arranged around a motor and its starting device.

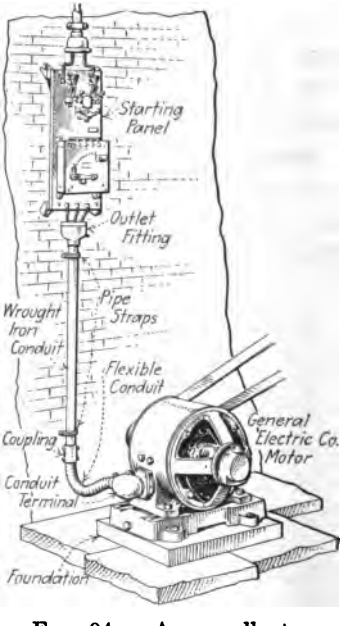


FIG. 94*a*.—An excellent example of a conduit-wired motor installation. (General Electric Company motor and starting panel.)

A conduit-wiring motor installation wherein a starting panel is used is shown in Fig. 94*a*. The installation illustrated is probably as compact and as neat a one as it is possible to make. Note that the motor is provided with a conduit-wiring ter-

minal box and that a starting panel requiring a minimum of wiring for its installation is employed. Flexible conduit is used between the vertical conduit run and the motor, permitting the ready removal and replacement of the motor.

8e. ¶I. MOTORS. Must not be run in series-multiple or multiple-series, except on constant-potential systems, and then only by special permission.

8f. ¶I. MOTORS. Must, if deemed necessary, be enclosed in an *approved* case.

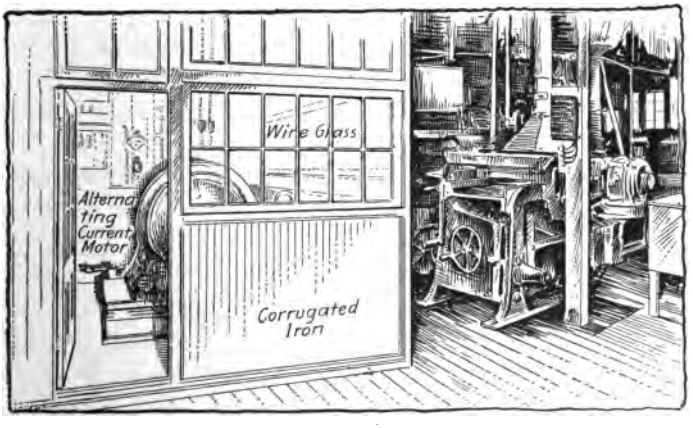


FIG. 95.—Non-combustible motor compartment.

8f. ¶II. MOTORS. Such enclosures must be readily accessible, dust proof and sufficiently ventilated to prevent an excessive rise of temperature. Where practicable the sides should be made largely of glass, so that the motor may be always plainly visible.

Motors located in wet, dusty or dirty places should ordinarily be enclosed either in a ventilated enclosure or in a room, Fig. 95, prepared for their reception. The room should be big enough so that the attendant can work around the apparatus without difficulty and it should be provided with windows and artificial light. Where the motor platform is suspended from a ceiling, a room can be arranged around it by providing glass partitions from the floor of the platform to the ceiling. It is seldom necessary to enclose alternating-current motors of the types in which brushes are not used.

8*f*. ¶*III*. MOTORS. **The use of enclosed type motor is recommended in dusty places, being preferable to wooden boxing.**

An enclosing case for motors located in dusty or linty places may be made as shown in Fig. 96. Such a case, as hereinbefore indicated, is not ordinarily necessary for alternating-current motors or for enclosed direct-current motors but should be provided for open direct-current motors unless the motors are protected from the lint and dirt by some other means. Such a case can be made from ⅞-in. tongued and grooved timber and should be lined with asbestos or preferably with sheet metal. In addition to having

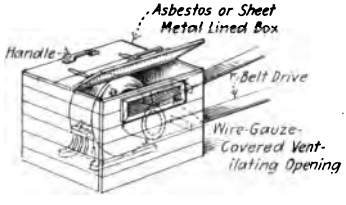


FIG. 96.—Enclosing case for an open direct-current motor in a dirty place.

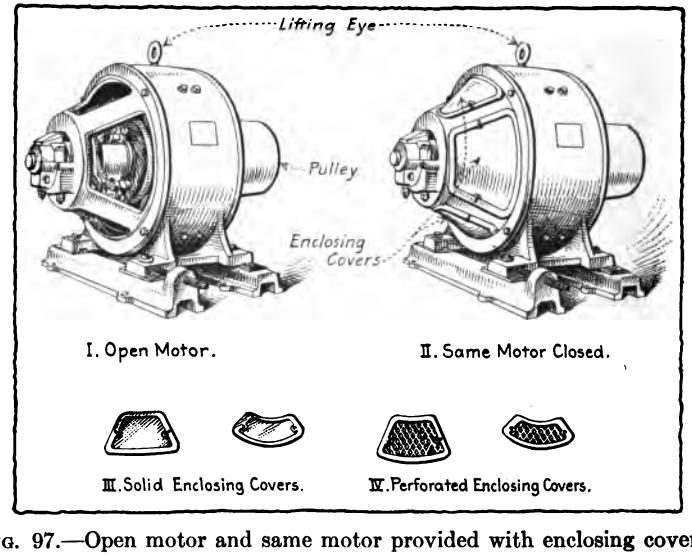


FIG. 97.—Open motor and same motor provided with enclosing covers.

the covers so that they will open as shown in the figure, it is very convenient to arrange the sides on hinges so that they can be let down to provide for the maintenance and inspec-

tion of the motor. Gauze-covered ventilating openings must be provided as shown, otherwise the motor is liable to overheat.

Enclosed motors have the advantage that all dust and dirt is excluded, but they have the disadvantage that enclosing a motor or any electrical machine, as shown in Fig. 97, *II*, so decreases the ventilation that the capacity of the motor is materially reduced. For example, if a motor has a capacity of 15 h.p. when open as shown in Fig. 97, *I*, the same motor enclosed, as shown at *II*, may have a capacity of only 7 h.p. Where it is desired to protect the working parts of the motor from mechanical injury rather than from finely divided particles, perforated covers *IV* can be used instead of the solid enclosing covers, *III*, without materially decreasing the output of the motor. As noted above it is seldom, if ever, necessary to enclose alternating-current motors of the types that do not have brushes.

8*f*. ¶*IV*. MOTORS. Where deemed necessary, motors permanently located on wooden floors must be provided with suitable drip pans.

Oil drip pans may, where necessary, be provided as shown in Fig. 98 to catch any oil that may drop from the bearings. Such oil, if allowed to fall on and soak into a wood floor or other combustible material, would greatly increase the fire hazard. It is seldom that it is necessary to provide modern motors with drip pans, inasmuch as their bearings are so designed that the oil does not ordinarily leak from them.

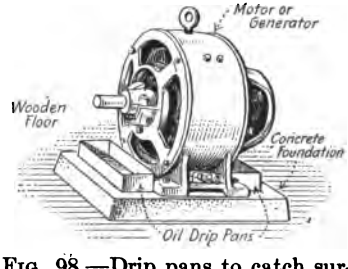
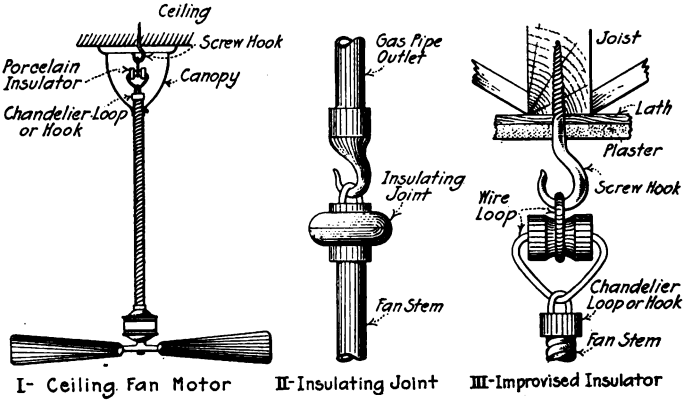


FIG. 98.—Drip pans to catch surplus oil from motor bearings.

8*g*. ¶*I*. MOTORS. Must, when combined with ceiling fans, be hung from insulated hooks, or else there must be an insulator interposed between the motor and its support.

Ceiling fan motors should be insulated from the ceiling as shown in Fig. 99, so that there will be no possibility of a leakage current to ground, causing a fire. The frames of ceiling fan motors are always thoroughly insulated from the supporting

surfaces inasmuch as it is not usually practical to ground them like it is ordinary motor and generator frames.



[FIG. 99.—Methods of insulating ceiling fan motors.

8h. ¶I. MOTORS. Must each be provided with a name-plate, giving the maker's name, the capacity in volts and amperes, and the normal speed in revolutions per minute.

Motor name plates are shown for a direct-current motor and for an alternating-current motor in Figs. 100 and 101 respectively. These name plates give information similar to that given on

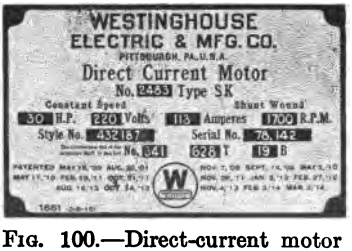


FIG. 100.—Direct-current motor name plate.

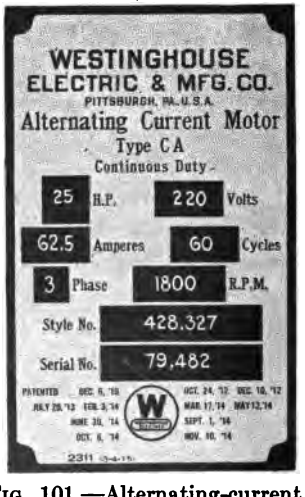


FIG. 101.—Alternating-current motor name plate.

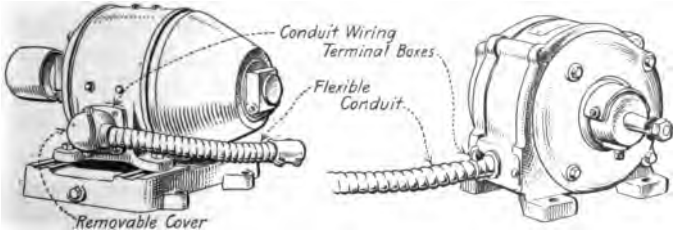
generator name plates (see discussion under *Rule* 1e, ¶*I*) and are required for the same reasons. The authoritative data

that they provide tend to prevent the possibility of the overloading and consequent overheating of the machines.

8*h*. ¶*II*. MOTORS. All varying (or variable) speed motors except those used for railway service must be marked with the maximum current which they can safely carry for 30 minutes, starting cold.

8*i*. ¶*I*. MOTORS. Terminal blocks when used on motors must be made of *approved* non-combustible, non-absorptive, insulating material such as slate, marble or porcelain.

Terminal blocks on motors perform essentially the same function as those on generators (Fig. 31) and hence are similarly constructed. Where motor wiring is to be installed in conduit



I. Direct-Current Motor. II. Alternating-Current Motor.

FIG. 102.—Conduit wiring terminal boxes on motors. (General Electric Co. motors.)

it is always desirable to secure motors provided with terminal boxes, Fig. 102, arranged for conduit wiring. Where these boxes are used, all of the conductors are enclosed and there are no loose ends or "pig tails" to catch dirt and lint.

All direct-current motors should be so wired that the field will be excited before current flows in the armature circuit of the motor. The armature of a direct-current motor (Fig. 103) has a very low resistance; hence, if the normal e.m.f. of the circuit is impressed upon it (with the armature stationary), a large current will flow which will probably melt fuses, and might, under some conditions, cause a fire due to overheating of certain parts. However, if the motor armature rotates in a magnetic field there is induced in it a counter e.m.f. When the armature of a direct-current motor rotates in its mag-

netic field, this counter e.m.f. is always in such a direction that it opposes the external e.m.f. which is applied to the motor and which causes rotation and thus the current through the armature circuit is limited to a safe value. It is apparent, then, that if the armature of a motor is connected across a supply circuit, the field circuit of the motor not being excited, the supply source will be short-circuited.

But if the field of the motor is first excited and then the armature is connected across the supply circuit, it will at once commence to rotate and induce the counter e.m.f. which will limit the current through it. However, rheostat, *R*, Fig. 103, should always be provided, in series with the supply circuit and the armature, to limit the current through the armature at the instant of starting. As the armature attains speed the resistance of this rheostat can be gradually decreased until finally, when the armature has attained full speed, it (the armature) may be connected directly across the line.

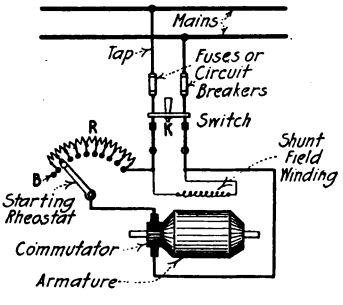


FIG. 103.—Showing diagrammatically correct method of connecting motor so that shunt field will be excited before current flows in armature.

NOTE in Fig. 103, when the motor is not operating, knife switch *K* should be open and the rheostat handle should be on button *B* so that the armature is not in circuit. Then, in starting the motor, *K* is closed. This permits current to flow through the shunt-field winding immediately. No current can flow through the armature until the rheostat handle has been moved one button to the right. Then a small current will flow through the armature, but when it does flow the field will be excited and the armature will commence to rotate.

8*j*. ¶*I*. MOTORS. Adjustable speed motors, unless of special and appropriate design, if controlled by means of field regulation, must be so arranged and connected that they cannot be started under weakened field.

8*k*. ¶*I*. MOTORS. The use of soft rubber bushings to protect the lead wires coming through the frames of motors is permitted, except when installed where oils, grease, oily vapors or other substances known to have rapid deleterious effect on rubber are present in such quantities and in such proximity to motors as may cause such bushings to be liable to rapid destruction. In such cases hardwood properly filled, or preferably porcelain or micanite bushings must be used.

Bushings for motor leads should be of non-absorbent and preferably of non-combustible materials for the same reasons (*Rules* 1*f* and *g*) that such materials are desirable for generator bushings.

9. RAILWAY POWER PLANTS.

9. RAILWAY POWER PLANTS. Each feed wire before it leaves the power plant must be protected by an *approved* automatic circuit-breaker or other device, which will immediately cut off the current in case of an accidental ground. This device must be mounted on a fire-proof base and in full view and reach of the attendant.

10. STORAGE OR PRIMARY BATTERIES.

10*a*. ¶*I*. STORAGE OR PRIMARY BATTERIES. When current for light and power is taken from primary or secondary batteries, the same general regulations must be observed as apply to similar apparatus fed from generators developing the same difference of potential.

Storage batteries are treated as sources of e.m.f. in so far as wiring for them is concerned, just as are generators. Hence, storage battery wiring is subject to the same general regulations as is that outlined for generators, except that, as suggested below, the fact that acid fumes are always present in storage battery rooms renders certain precautions, which will be suggested, necessary.

10*b*. ¶*I*. STORAGE OR PRIMARY BATTERIES. Storage battery rooms must be thoroughly ventilated.

The ventilation of storage-battery rooms is imperative. There are two reasons for this. The first and most important is that during the process of charging a storage cell, considerable volumes of hydrogen and oxygen gas are liberated. Unless these are carried off into the outer atmosphere by effective ventilation, it is possible for them to unite in proportions

constituting a highly explosive mixture. Such a mixture might be exploded by a spark, causing serious damage and possibly a fire. The second reason that ventilation is essential is because the acid fumes from the cells, unless they are carried off into the outer atmosphere, charge the air inside of the room and render it harmful to the health of the attendants. These fumes also tend to increase corrosive action on any exposed metal parts. The acid fumes of a storage-battery room do not attack lead, which is the only metal of reasonable cost that can, unprotected, be used in these locations without danger from corrosion.

10c. ¶*I*. STORAGE OR PRIMARY BATTERIES. Special attention is directed to the rules for wiring in rooms where acid fumes exist (see No. 26, *i* and *j*).

The presence of acid fumes necessitates special methods of wiring whereby the brass or copper of the conductors, which is very readily attacked, is protected from the action of the acid vapors. Wiring of the same general character is required in these locations as in dye houses, breweries, chemical works and similar places, the methods of installing which are described under *Rule* 26*i* and *j*. It is probable that the wiring in a storage battery room is subject, in so far as acid-vapor action is concerned, to more severe conditions that those which obtain in any other location in which wiring is installed.

10*d*. ¶*I*. STORAGE OR PRIMARY BATTERIES. All secondary batteries must be mounted on non-absorptive, non-combustible insulators, such as glass or thoroughly vitrified and glazed porcelain.

Storage cells are mounted on vitrified insulators to minimize the leakage currents that would flow if the cells were mounted directly on ordinary wood supports or on bases of any material that might become saturated with acid. This applies particularly to cells having (Fig. 104) outer tanks of wood or other materials which may absorb moisture. After wood or any similar material has been allowed to remain in a storage-battery room for a relatively short time it may absorb acid and thereby become a fairly good conductor. Furthermore, a film of acid may form on the outer sides of the jars

containing the cells, and, even if they are of hard rubber, provide a conducting path. It is for these reasons that it is difficult to insulate storage cells thoroughly from ground. Experience has shown that glass or porcelain insulators should always be interposed between the storage-cell jar and ground. A glass jar for a storage cell is of itself usually considered to provide adequate insulation.

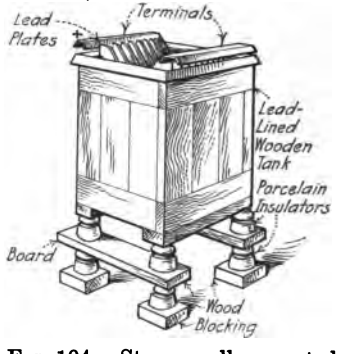
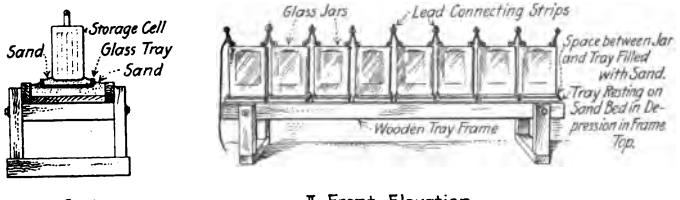


FIG. 104.—Storage cell supported on porcelain insulators.

Porcelain insulators used for supporting a large wooden storage-cell tank are shown in Fig. 104. The insulators, eight in number, are of glazed porcelain of the type used in high-voltage power transmission line construction. Each insulator is supported on a wooden pin, not visible in the illustration, set in the block under the insulator. The top of each insulator rests in a depression in the plank above it.

Glass trays used for supporting storage cells are shown in Fig. 105. The wooden supporting frame is so constructed that its top surface constitutes a depression, which is filled



I. End Section. II. Front Elevation.

FIG. 105.—Storage cell supported on glass trays filled with sand.

with sand. On this layer of sand the glass trays are bedded. The sand assures even bedding. Then each of the trays is filled with sand and a glass storage cell is bedded on the sand in each tray. The sand in the trays therefore performs two functions. *First*, it provides an even bedding for the cell,

and *second*, it collects any acid-laden moisture that may condense and flow down on the sides of the glass jars, preventing the condensation from saturating the sand on the top of the wood frame. It is necessary to change the sand in the trays occasionally. The sand in the top of the frame should also be changed but less frequently than that in the trays. The glass trays in this case may be considered as additional insulators.

10*e*. ¶*I*. STORAGE OR PRIMARY BATTERIES. The use of any metal liable to corrosion must be avoided in cell connections of secondary batteries.

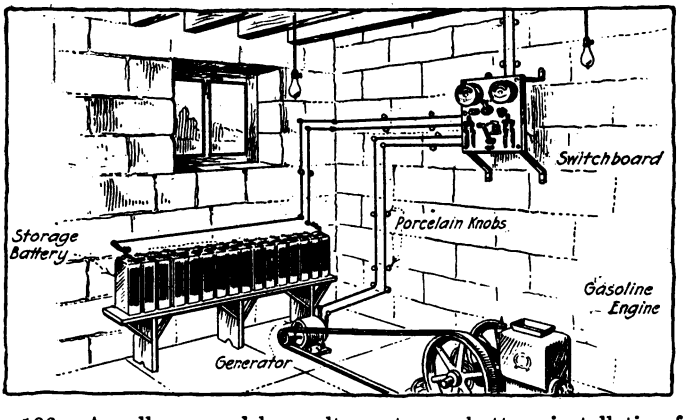


FIG. 106.—A well-arranged low-voltage storage battery installation for farm lighting.

This is a 30-volt lighting set. Where the container of each cell is a glass jar the jar itself may be considered a "non-absorptive non-combustible insulator" thus rendering further insulation of each cell unnecessary.

Lead is used for storage-cell connections because it is the only metal commercially available which is unaffected by the acid fumes. Where it is necessary that metals other than lead be used in a storage-battery room, they must be protected either with lead or by one of the methods described in *Rule* 26*j*. If brass or copper were used unprotected, the acid action would probably so reduce their cross-section that the current which the conductor was originally installed to carry would fuse it, and might thereby cause a fire or an explosion.

A low-voltage storage battery installation is shown in Fig. 106.

11. TRANSFORMERS.

(*See also Nos.* 14, 15, 36 *and* 45. *For construction rules see No.* 81.)

NOTE that the following rules (*Rule* 11*a* and *b*) relate only to transformer installations in general. The installation methods for outdoor transformers for all systems and voltages are given under *Rule* 14. Grounding of transformer secondaries is discussed under *Rules* 14 and 15. Regulations affecting transformers installed indoors on low-potential systems (550 volts or less) are recited under *Rule* 36. Requirements for high-potential transformers (550 to 3,500 volts) are outlined in *Rule* 45. *Rule* 81 gives requirements which should be followed in constructing or manufacturing transformers.

11*a*. ¶*I*. TRANSFORMERS. In central or sub-stations the transformers must be so placed that smoke from the burning out of the coils or the boiling over of the oil (where oil filled cases are used) can do no harm.

In locating transformers within buildings it should be remembered that a large transformer contains considerable combustible material. It is possible for an insulation breakdown, due possibly to a lightning discharge or a surge, to result in a fire within the transformer. The insulation burns with a heavy dense smoke and produces the effect of a very serious fire. The result may be that streams of water will be thrown on the apparatus in the building, incurring considerable damage thereto. Furthermore, the oil in the transformer case may become ignited and boil over. Such a fire is very difficult to handle.

A safe indoor transformer installation is shown in Fig. 107. The walls of the enclosing room or addition should be of brick, hollow tile, or stone. A fire door of approved construction separates the transformer room from the building which adjoins it. The roof is a concrete slab reinforced with steel bars. A ventilator is provided to carry off fumes, should they exist, and to keep the room cool. The floor should slope toward the drain so that if the oil leaks from the tank or boils over from it, it will flow out of the building. The drain should

empty into a stream or be arranged some way so that the transformer oil, if it does flow through it, cannot accumulate. Frequently transformer houses are arranged with grating floors having a space underneath them so that if the transformer oil leaks it will drip down through the grating and not collect on the floor near the transformer.

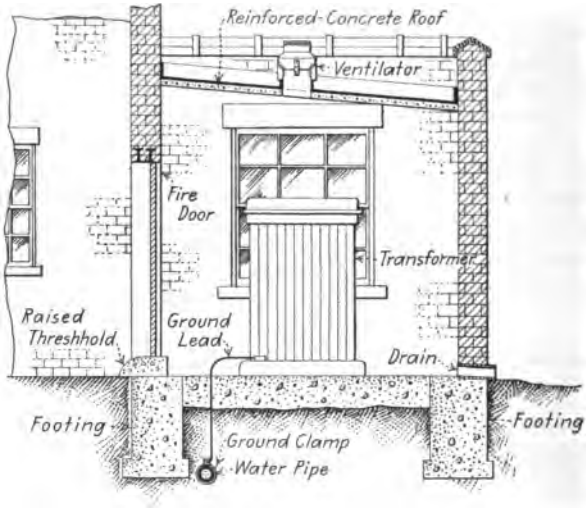


FIG. 107.—Transformer house of non-combustible materials.

11b. ¶I. TRANSFORMERS. In central or sub-stations casings of all transformers must be permanently and effectively grounded.

The Grounding of a Transformer Casing.—Where the casing of a transformer is thoroughly grounded as shown in Fig. 107, or by any of the methods described under *Rule* 15g, the fire hazard is decreased for the reasons outlined in connection with Generators under *Rule* 1c. Furthermore, if a transformer case is grounded, it will be impossible for an attendant standing on a grounded surface and touching the transformer case to receive a shock, even if the transformer case has, because of some accident or breakdown, become "charged" from accidental contact with the conductors it contains. Where a transformer case of any character is grounded, all of the ad-

jacent metal work should be grounded also to prevent accidents.

11b. ¶*II*. TRANSFORMERS. The cases or frames of transformers used exclusively to supply current to switchboard instruments must be grounded unless they are installed and guarded in all respects as required for the higher voltage circuit connected to them.

Grounding of instrument-transformer cases, while not mandatory, is considered desirable in every case where the voltage exceeds, say, 220 because it decreases the possibility of shock to attendants as suggested above. The power associated with an instrument-transformer circuit is seldom great enough to involve any considerable fire hazard. Not alone should the transformer casings be grounded but also the metal switchboard frames, the instrument cases, conductor supports and all other adjacent conducting members that do not constitute portions of the electrical circuits should be grounded.

Questions. Class A

1. In what kind of a place should a generator always be installed, and why?
2. Should, or should not, the frames of generators be grounded, and why?
3. Should generator frames ever be insulated from ground? If so, under what conditions?
4. What overload protection is required for two-wire, direct-current generators, and how must such overload protection be installed in the circuit?
5. What overload protection should be provided for three-wire direct-current generators and how should it be arranged?
6. What data is required on a generator name plate?
7. In general, what kind of conductors should be used for leads between a generator and its switchboard, and how should they be installed?
8. Give number and location of lightning arresters required on overhead line wires entering power plants.
9. What size wires should be used for the main leads of a 25-h.p., 220-volt, direct-current motor, assuming that the voltage drop in the leads need not be considered? The motor has an efficiency of 85 per cent.
10. Describe the principle of operation of a ground detector for a two-wire circuit, which uses incandescent lamps as indicators.
11. How should resistance devices be installed on switchboards?
12. Should the frames of motors ever be grounded, and if so, why, and under what conditions?
13. How much excess current-carrying capacity should the lead wires serving a motor have over its normal full-load current rating?
14. What are the general requirements governing the installation of switchboards as regards their location.
15. What kind of insulation is required on wires used for connecting resistor elements and contact devices of a rheostat, and why?
16. Should the frames of motors ever be insulated from ground and if so, why and under what conditions?

17. In running the ground wire from a lightning arrester, what is the smallest size conductor that may be used and, in general, how should this wire be run?

18. What is the minimum permissible distance between the wiring on the back of a switchboard and the nearest wall or partition, and how far should the top of the board be from the ceiling?

19. What special precautions and requirements must be observed in the installation of storage or primary batteries? Give the reasons for these requirements.

20. How should all motors be controlled and protected against overloads?

21. In determining the size wire required for serving one alternating-current motor what is the procedure followed, and why?

22. State the general requirements regarding the installation and grounding of transformers in central stations.

23. State under what conditions motors and starters should be enclosed, and why.

24. Where should a motor and its control apparatus be placed in respect to one another?

25. Upon what basis must the wire size of the branch leads serving a variable-speed motor be determined?

26. May generators be located in places exposed to inflammable gases or flyings of combustible materials? State reasons for your answer.

27. When wood base frames are used for insulating generators from ground, what requirements govern their installation?

28. Are bare bus bars permitted in central stations, dynamo, motor and storage battery rooms, transformer substations, etc., or must they be insulated?

29. How should oily waste in generator rooms be disposed of?

30. How should secondary batteries be mounted?

31. When generators are installed in rooms subject to dust or combustible flyings, what are the requirements affecting their installation?

32. Under what conditions may a switchboard be supported directly against a brick or stone wall?

33. What kind of conductors must be used when wiring for motors operating at a difference of potential between 550 and 3500 volts?

34. When incandescent lamps are used as protective resistance devices, how are they installed? What special requirements govern their use?

35. What requirements are in effect regarding the flameproof coverings of conductors used in switchboard wiring?

36. How should generator terminal blocks be constructed?

37. What rulings govern the installation of generator conductors not in conduit?

38. What special protection may be required when wires with inflammable outer braiding are brought close together in the rear of switchboards?

39. Under what conditions may the switch ordinarily required for the control of motors and their starting devices be omitted?

40. When is the use of soft rubber bushings for generator leads prohibited? Why?

41. Where must the safety device required in the circuit of a grounded two-wire generator, not electrically driven, be placed?

42. How should motors combined with ceiling fans be installed?

CLASS B

(Rules 12 to 15 inclusive)

OUTSIDE WORK*

(Not Including Wiring for Light, Power and Heat Protected by Service Cut-out and Switch. For Signaling Systems see Class E.)

ALL SYSTEMS AND VOLTAGES.

12. WIRES.

12*a*. ¶*I*. WIRES. Line wires must have an *approved* weatherproof or rubber insulating covering. That portion of the service wires between the main cut-out and switch and the first support from the cut-out or switch on outside of the building must have an approved rubber insulating covering, but from the above-mentioned support to the line, except when run in conduit, may have an *approved* weatherproof insulating covering if kept free from awnings, swinging signs, shutters, etc.

Rubber-insulated wire must be used in making an entrance, as shown in Fig. 108. The wire outside of the building (with

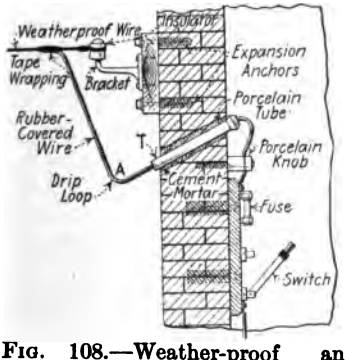


FIG. 108.—Weather-proof and rubber-insulated wire at entrance.

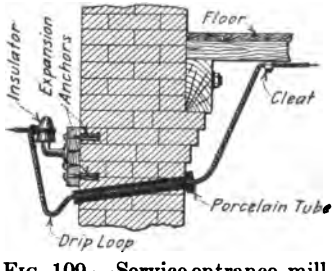


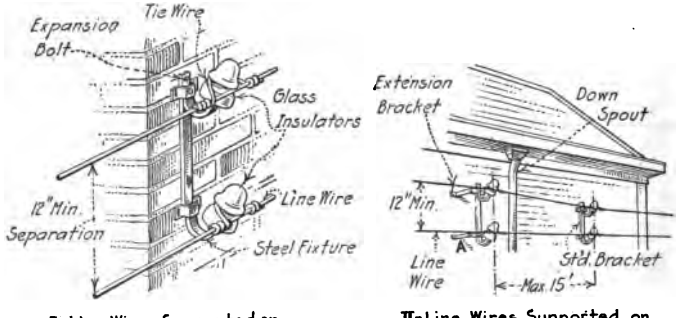
FIG. 109.—Service entrance, mill-construction building.

the exception of that from the last support to the point of entrance) may have weatherproof insulation if it is properly

* *The National-Electrical-Code* Class "B" rules (those which relate to "Outside Work"), particularly those affecting aerial-pole-line construction, have not been very rigidly enforced in many communities. The reason for this has probably been the fact that only such portions of the "Code" as are enacted into local ordinances or statutes have legal force. For all practical purposes it may be assumed that this Sect. B of the *Code* has been, or will ultimately be, superseded by Part II of the *National Electrical Safety Code*, which has been prepared by the United States Bureau of Standards, Washington. A copy of this Bureau-of-Standards publication, No. 54, will be furnished by the Superintendent of Documents, Government Printing Office, Washington, D. C., for twenty (20c) cents.

supported away from members that tend to interfere, but between the *last point of support* outside of the building and the main-cut-out-switch rubber-insulated wire must be used as illustrated in Fig. 108. Such an entrance wire, where it passes through the wall to the interior of the building, is subjected to moisture, which renders desirable the use of the best possible insulation on it. Another entrance installation is shown in Fig. 109.

12*b*. ¶*I*. WIRES. Line wires must be so placed that moisture cannot form a cross connection between them; must be not less than one foot apart except when in conduit or in the form of multiple conductor cable; must not be in contact with any substance other than their insulating supports. Multiple conductor cables must be secured to strain insulators spaced not less than one foot from any adjacent woodwork and in turn secured to petticoat or strain insulators by strain wires.



I-Line Wires Supported on Brick Wall

II-Line Wires Supported on Outside of Frame Building

FIG. 110.—Approved methods of supporting conductors on building exteriors.

In carrying conductors on the outsides of buildings they may where unprotected from the weather be supported on standard fixtures as indicated in Fig. 110. In purchasing such brackets care should be taken to select those that provide at least the 1-ft. separation required between conductors. In Fig. 110, *II*, *A*, is shown a special extension bracket whereby the conductors are supported a considerable distance from the side of the building to avoid contact with the downspout.

12*b*. ¶*II*. WIRES. For conduit work the general rules for conduit installations must be followed and the conduit system must be waterproof.

A conduit system installed out of doors must be waterproof to prevent moisture from short-circuiting the conductors within the duct. To be waterproof a conduit system must be so arranged that water cannot enter it. To meet this requirement it is frequently necessary to use white lead or conducting paint on the threads of the ducts and fittings before they are assembled, and to use rubber gaskets under the fitting covers. Where an entrance or service head fitting is used, as in Fig. 111, the wire openings of the fitting should always "look" down in such a way that the water cannot enter them.

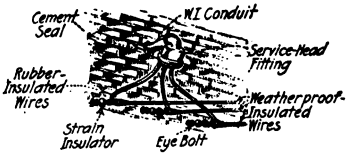


FIG. 111.—Conduit service entrance (service conductors dead ended on strain insulators).

12c. ¶ *I*. WIRES. Must be at least eight feet above the highest point of roofs over which they pass or to which they are attached, and roof structures must be substantially constructed. Wherever feasible, wires crossing buildings should be supported on poles independent of the buildings.

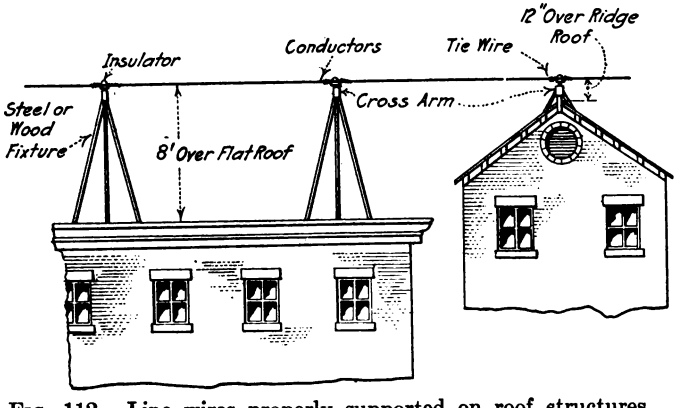


FIG. 112.—Line wires properly supported on roof structures.

Roof structures should, as shown in Fig. 112, carry their wires at least 8 ft. above flat roofs so that persons on the roofs can readily walk under the wires and so that, even if the wires do sag, they will not be likely to touch the roofs. With a peak

roof, a 1-ft. clearance, as shown in Fig. 112 was recommended in the 1913 CODE. No reference to the clearance over a peak roof is given in the 1915 edition. It is probable, however, that a 1-ft. clearance is sufficient, because with a roof of this type there is little likelihood of a person who is on the roof contacting with the wires or of the wires sagging sufficiently to touch the roof. Roof structures may be effectively made of wrought-iron pipe and fittings or of structural steel. These materials provide more sightly and probably in the long run more economical supports than does wood.

12*d*. ¶*I*. WIRES. Must, where exposed to the weather, be provided with petticoat insulators of glass or porcelain; porcelain knobs or cleats and rubber hooks will not be approved. Wires on the exterior walls of buildings must be supported at least every fifteen feet, the distance between supports to be shortened if wires are liable to be disturbed.

Petticoat insulators are shown in Fig. 113. Insulators of this general type should be used for all exposed out-of-door

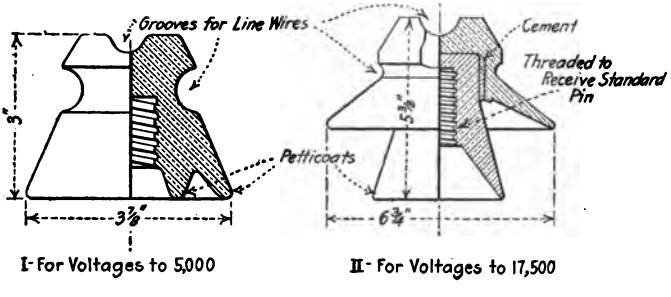


FIG. 113.—Porcelain petticoat insulators.

conductors on which a pressure exceeding, possibly, 25 volts is imposed, for the reason that ordinary porcelain knobs or cleats collect so much moisture on their surfaces during rain that their insulating values become very low. Such a film of moisture will greatly reduce the insulation resistance of an insulator and in some cases will render the insulator practically useless. Where petticoat insulators, similar to those of Fig. 113 are used, there will practically always be a dry surface under the petticoats at the bottom of the insulator, maintain-

ing the insulation resistance of the insulator at a dependable value. The "umbrella" edges of an insulator of this type tend to prevent the moisture from collecting on the bottom surfaces and even if they do not keep the "petticoats" entirely dry, they are very effective in sustaining high insulation resistance. While the above rule (*Rule* 12*d*, ¶*I*) presumably relates to "*All systems and Voltages*" (see heading of Section above *Rule* 12) it is a fact that porcelain knobs are permitted (*Rule* 85*c*) for the support of outside signal wires.

Supports should be provided every 15-ft. for conductors on exterior walls of buildings (Fig. 110). If the supports are placed very much farther apart than this there is a possibility of excessive sag in the wires and they may in some cases be deflected laterally and rest against the side of the building which supports them. Where downspouts or shutters are so located that they might interfere with conductors carried on the sides of buildings, additional brackets should be so placed as to prevent any possibility of such interference as shown in Fig. 110.

12*d*. ¶*II*. WIRES. Where not exposed to the weather, low potential wires may be supported on glass or porcelain knobs which will separate the wires at least one inch from the surface wired over, supports to be placed at least every four and one-half feet.

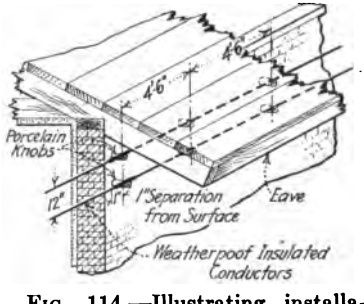


FIG. 114.—Illustrating installation of conductors protected from the weather.

Low-potential outside wires, unexposed to the weather, may be supported on porcelain knobs as shown in Fig. 114. That is, wires having impressed on them a voltage of 550 or less may be carried on knobs or porches or under eaves or where they are in some similar manner protected from the rain and moisture. Inasmuch as it is necessary to support such wires only 1 in. from the surface wired over, the supports should not be more than 4 ft. 6 in. apart. If the supports are further apart than this there is a possibility of the conductors

contacting with the surface on which they are carried. Signal wires may be carried on knobs even if exposed to the weather (*Rule* 85c).

12e. ¶*I*. WIRES. Must be so spliced or joined as to be both mechanically and electrically secure without solder. The joints must then be soldered, to insure preservation, and covered with an insulation equal to that on the conductors.

Splices in wires should, if the splices are to be as strong unsoldered as the wires composing them, have at least five twists in the neck, as shown in Fig. 115. There is always a possibility of a loose connection at an unsoldered joint. An arc may form between the wires of a loose connection and melt the wires in two. Then soldering the splice further increases its strength and insures permanence and ample electrical conductivity. To insulate a splice, it is wrapped, as shown in Fig. 116, with insulating materials of the same thick-

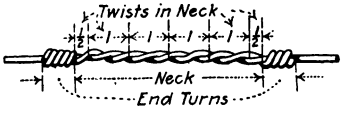


FIG. 115.—Properly-made bare-wire joint. (Note that in the "neck" there are 4 complete twists and 2 half twists making 5 complete twists.)

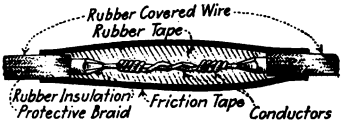


FIG. 116.—Showing the method of making and insulating a joint in "rubber-covered" wire.

ness and of the same composition as those comprising the insulation on the wire in which the splice is made. For example, to insulate a splice in a rubber-insulated wire (Fig. 116) the splice is first wrapped with rubber tape to a thickness at least equal to that of the rubber insulation around the perfect wire. Then over this a wrapping of friction tape equivalent to the braid of the conductor is served. The friction tape layer should be at least as thick as the braid serving on the perfect wire. For further information relating to the making of splices, see the author's AMERICAN ELECTRICIANS' HANDBOOK.

To insulate a splice in wire with weatherproof insulation the wire may be served with friction tape only, to a thickness of the weatherproof insulation on the perfect conductor.

A tap splice in a conductor is made as shown in Fig. 117. The bared end of the tap conductor is given a few long or "neck" twists around the main conductor and then the joint is finished off by serving four or five short end turns around the main conductor. The same rules and procedure are followed in insulating a tap splice as for a main-line splice like that of Fig. 116.

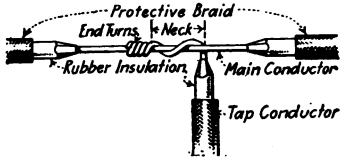


FIG. 117.—A tap joint in conductors.

In splicing duplex or twin conductors the joints should be "staggered," as suggested in Fig. 118, so that there can be no possibility of the two joints contacting with each other and so that the bulge or

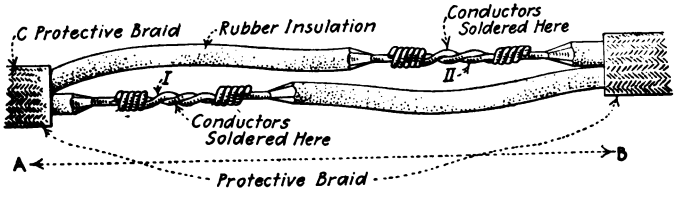


FIG. 118.—Showing how the joints in a twin-wire splice should be "staggered."

enlargement that is made in insulating the two joints will not occur at one location. After a twin wire has been spliced by joining its two component wires as shown in Fig. 118 at

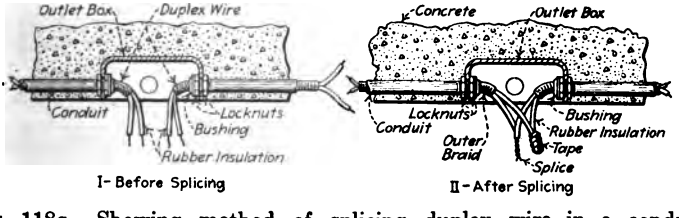


FIG. 118*a*.—Showing method of splicing duplex wire in a conduit installation.

I and *II*, and after each of these component splices has been insulated with the tape serving of the material of the insulation next to the wire, then the entire joint should be again

served from *A* to *B* with friction tape, at least equivalent in thickness to the protective braid *C* on the twin wire. In conduit wiring, no splices are permitted except in outlet boxes (*Rule* 26–¶*I*) hence, in conduit work the conductors are spliced as shown in Fig. 118*a*.

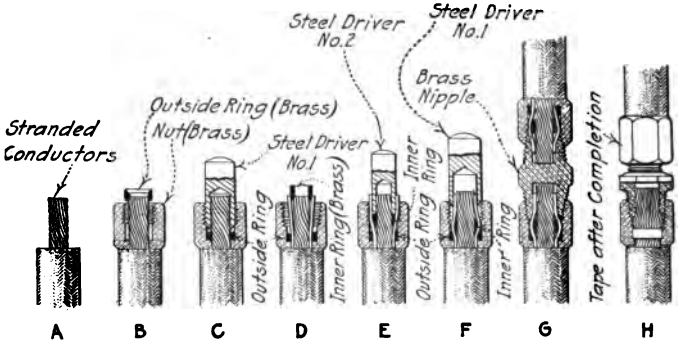


FIG. 119.—Process of making a splice in stranded conductor with a mechanical connector (Dossert).

12*e*. ¶*II*. WIRES. All joints must be soldered, unless made with some form of *approved* splicing device.

Approved splicing devices are manufactured, but have been applied more extensively for inside than for outside work. Figs. 119 and 120 show details of two types of the Dossert

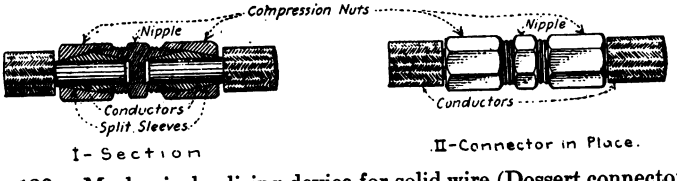


FIG. 120.—Mechanical splicing device for solid wire (Dossert connector).

connector. All of these splicing devices are so designed that the two ends of the conductor which is to be joined are clamped, usually by a wedging action, by the device. Soldering is unnecessary. The electrical conductivity of a good joint of this type appears to be at least equal to that of a similar length of the wire itself. The mechanical strength of such a

joint is usually at least equal to 75 per cent. of that of the wires joined, and may be equal to the strength of the wires joined. The Dossert connector for stranded wire is shown in Fig. 119.

Splicing Device for Stranded Conductor.—To make a joint with this connector the wire (Fig. 119) is first stripped and cleaned (*A*) for a distance 3/16 in. longer than the compression nut. Then (*B*) the compression nut and outside ring are slipped on and driven home (*C*) with a cupshaped steel driver designed for the purpose. The outer strands are separated and the inner ring is pushed on over the central core (*D*) and driven home with another steel driver (*E*). Now the outside strands are formed back into the position (*F*) and the nipple is screwed in place, which still further compresses the conductors as shown in *G*.

A splicing device for solid conductor is shown in Fig. 120. With this device (Dossert Manufacturing Company) the inner

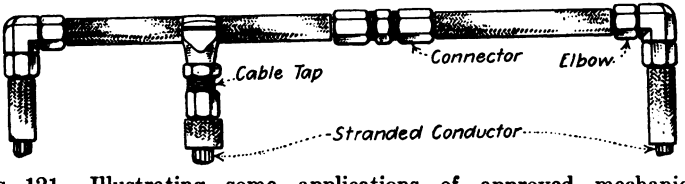


FIG. 121.—Illustrating some applications of approved mechanical splicing devices.

parts are shaped to receive a double, conical split sleeve, which grips the wire with a chuck-like action. By heading over the end of the wire a trifle after it has been slipped within the split sleeve, an increase in mechanical strength is obtained.

Mechanical-splicing T's, crosses and terminal lugs (Fig. 121) can be purchased. They all involve constructional principles similar to those described in connection with Figs. 119 and 120.

12*f*. ¶*I*. WIRES. Must, where they enter buildings, have drip loops outside, and the holes through which the conductors pass must be bushed with non-combustible, non-absorptive, insulating tubes slanting upward toward the inside.

The service entrance into a mill-construction building may

be arranged as shown in Fig. 109. The aerial weatherproof-insulated outside conductor is terminated on a glass insulator. The rubber-insulated conductor to the inside is carried through the brick wall in a porcelain-tube bushing. The wood block upon which the glass-insulator bracket is held with screws is supported to the brick wall with expansion anchors.

Drip loops are bent in conductors just outside of the point where the conductors enter a building to prevent the entrance of moisture around the wire, as shown in Figs. 108, 109 and 122. If rain does collect on the wire it will follow the wire down to the lowest point, *A* (Fig. 108), and there fall off. None will enter the tube *I*.

Porcelain tubes are used to provide insulation where conductors enter buildings (Figs. 108 and 109). The tube should slant down from the inside so that condensed moisture will not flow through the tube to the inside of the building. The heads of the tubes should always be inside of the building to prevent them from slipping out of position. In brick or masonry walls it is good practice to cement the entrance tube in position in the wall with plaster of Paris or with Portland cement mortar, one-half by volume of sand and one-half of cement as shown in Fig. 108.

12*f*. ¶*II*. WIRES. For low-potential systems the service wires may be brought into buildings through a single iron conduit. The conduit to be equipped with an *approved* service-head. The inner end must extend to the service cut-out, and if a cabinet is required by the Code must properly enter the cabinet.

Conduit service entrances are arranged substantially as suggested in Fig. 122. The approved service heads are provided with insulating outlet bushings, *B*, which separate the wires a safe distance, *D*, where they leave the fitting and prevent the abrasion of the insulation on the conductor by sharp metallic edges. As the illustration shows, the conduit entrance pipe must extend to the service cut-out, or if an entrance switch cabinet is required, the conduit must extend to and enter this cabinet. Since the cellar is now usually considered the most desirable location at which to enter a building, conduit entrances are very frequently installed, conduit providing the

most satisfactory support for the conductors down the side of the building. Note that conduit entrances are permitted only for "low-potential" systems involving pressures of 550 volts or less. The section of conduit used in making an entrance should be installed in accordance with the general requirements of *Rule* 28 for all conduit installations. The wire in the conduit must be rubber-insulated. Where the conduit passes through a masonry wall as at *M*, Fig. 122, the space between the outside of the conduit and the sides of the

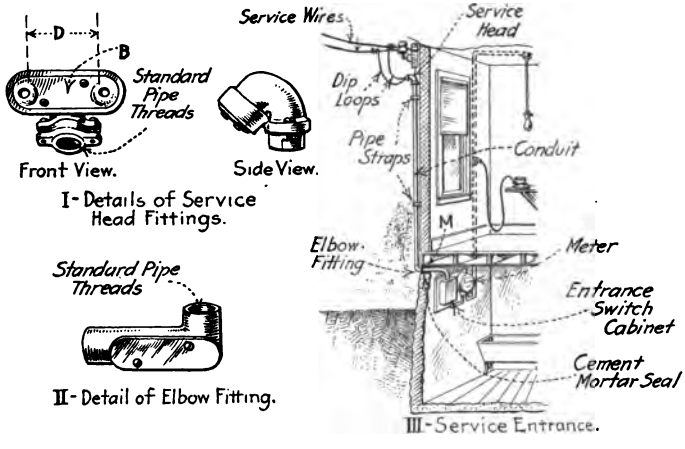


FIG. 122.—A conduit entrance.

hole through the masonry should be sealed with Portland cement mortar, as shown around the tube in Fig. 108.

The height at which service entrance wires should be attached to a building is not specified by the CODE, but it is considered good practice to locate this entrance at least as high as the ceiling of the first floor. Where this is done there will be little danger of the service wires being interfered with by persons walking on the ground.

A method of making a service entrance by carrying the conduit down inside of a building is shown in Fig. 111. The weatherproof conductors in this case are dead-ended on strain insulators; the rubber-insulated conductors extending from

the inside of the building, tap on the weatherproof-insulation wires.

12*f*. ¶*III*. WIRES. Metal conduits containing service wires must be insulated from the metal conduit, metal moulding, or armored cable system within the building and all metal work on or in the building or they must have the metal of the conduit permanently and effectually grounded to water piping, gas piping or other suitable grounds, provided that when connections are made to gas piping, they must be on the street side of the meter. This ground connection to be independent of and in addition to any other ground wire on metal conduit, metal moulding or armored cable systems within the building.

12*f*. ¶*IV*. WIRES. If conduit, couplings or fittings having protective coating of non-conducting material such as enamel are used, such coating must be thoroughly removed from threads of both couplings and conduit, and such surfaces of fittings where the conduit or ground clamp is secured in order to obtain the requisite good connection. Grounded pipes must be cleaned of rust, scale, etc., at place of attachment of ground clamp.

The reason why the non-conducting material should be removed from threads, that is, why the electrical continuity of the conduit system must be good is explained under *Rule* 28*f* ¶*III*.

12*f*. ¶*V*. WIRES. Connections to grounded pipes and to conduit must be exposed to view or accessible, and must be made by means of *approved* ground clamps.

Why the above requirement should be followed is explained in the Conduit Wiring information under *Rule* 28*f* ¶*IV*.

12*f*. ¶*VI*. WIRES. Ground wires must be of copper, at least No. 6 B. & S. gage (where largest wire contained in conduit is not greater than No. 0 B. & S. gage), and need not be greater than No. 4 B. & S. gage (where largest wire contained in conduit is greater than No. 0 B. & S. gage). They shall be protected from mechanical injury.

12*f*. NOTE.—WIRES. The ground on the conduit system is not to be considered as a ground for the secondary system (See No. 15).

The methods of grounding conduit systems are described under the subject of Conduit Wiring under *Rule* 28*f* ¶*I to V*.

12*g*. ¶*I*. WIRES. Electric light and power wires must not be placed on the same cross-arm with telegraph, telephone or similar wires, and

when placed on the same pole with such wires the distance between the two inside pins of each cross-arm must not be less than twenty-six inches.

12*h*. ¶*I*. WIRES. The metallic sheaths of cables must be permanently and effectively connected to "earth" approximately every 500 ft.

12. TROLLEY WIRES.

12*i*. ¶*I*. TROLLEY WIRES. Must not be smaller than No. 0 B. & S. gage copper or No. 4 B. & S. gage silicon bronze, and must readily stand the strain put upon them when in use.

12*j*. ¶*I*. TROLLEY WIRES. Must have a double insulation from the ground. In wooden pole construction the pole will be considered as one insulation.

12*k*. ¶*I*. TROLLEY WIRES. Must be capable of being disconnected at the power plant, or of being divided into sections, so that in case of fire on the railway route, the current may be shut off from the particular section and not interfere with the work of the firemen. This rule also applies to feeders.

12*l*. ¶*I*. TROLLEY WIRES. Must be safely protected against accidental contact where crossed by other conductors.

12*l*. ¶*II*. TROLLEY WIRES. Where guard wires are used they must be insulated from the ground and electrically disconnected in sections of not more than 300 feet in length.

13. CONSTANT-POTENTIAL POLE LINES, OVER 5,000 VOLTS.

13. NOTE.—CONSTANT-POTENTIAL POLE LINES, OVER 5,000 VOLTS. (Overhead lines of this class unless properly arranged may increase the fire loss from the following causes:—

¶*I*. Accidental crosses between such lines and low-potential lines may allow the high-voltage current to enter buildings over a large section of adjoining country. Moreover, such high-voltage lines, if carried close to buildings, hamper the work of firemen in case of fire in the building. The object of these rules is so to direct this class of construction that no increase in fire hazard will result, while at the same time care has been taken to avoid restrictions which would unreasonably impede progress in electrical development.

¶*II*. It is fully understood that it is impossible to frame rules which will cover all conceivable cases that may arise in construction work of such an extended and varied nature, and it is advised that this Department be freely consulted as to any modification of the rules in particular cases.)

13*a*. ¶*I*. CONSTANT-POTENTIAL POLE LINES, OVER 5,000 VOLTS. Every reasonable precaution must be taken in arranging routes so as to avoid exposure to contacts with other electric circuits. On existing lines, where there is a liability to contact, the route should be changed by mutual agreement between the parties in interest wherever possible.

13*b*. ¶*I*. CONSTANT-POTENTIAL POLE LINES, OVER 5,000 VOLTS. Such lines should not approach other pole lines nearer than a distance equal to the height of the taller pole line, and such lines should not be on the same pole with other wires, except that signaling wires used by the Company operating the high-pressure system, and which do not

enter property other than that owned or occupied by such Company may be carried over the same poles.

If two pole lines are not separated by a distance at least equal to the height of the taller pole line, if the taller poles are blown over they may fall on the lower line. Where the heights are in accordance with the above requirements such interference is impossible.

13*c*. ¶*I*. CONSTANT-POTENTIAL POLE LINES, OVER 5,000 VOLTS. Where such lines must necessarily be carried nearer to other pole lines than is specified in Section *b* above, or where they must necessarily be carried on the same poles with other wires, extra precautions to reduce the liability of a breakdown to a minimum must be taken, such as the use of wires of ample mechanical strength, widely spaced cross-arms, short spans, double or extra heavy cross-arms, extra heavy pins, insulators, and poles thoroughly supported. If carried on the same pole with other wires, the high-pressure wires must be carried at least three feet above the other wires.

13*d*. ¶*I*. CONSTANT-POTENTIAL POLE LINES, OVER 5,000 VOLTS. Where such lines cross other lines, the poles of both lines must be of heavy and substantial construction.

13*d*. ¶*II*. CONSTANT-POTENTIAL POLE LINES, OVER 5,000 VOLTS. Whenever it is feasible, end-insulator guards should be placed on the cross-arms of the upper line. If the high-pressure wires cross below the other lines, the wires of the upper line should be dead-ended at each end of the span to double-grooved, or to standard transposition insulators, and the line completed by loops.

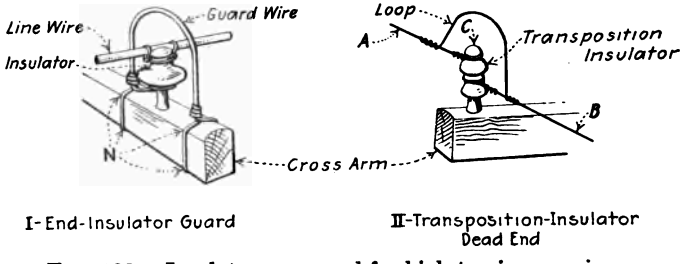


FIG. 123.—Insulators arranged for high-tension crossings.

An end-insulator guard formed of heavy iron wire is shown in Fig. 123, *I*. The function of such a guard is to prevent the wire supported on the insulator within it from falling from the crossarm and on to the wires below in case the tie wire becomes broken. In placing a guard wire of this character on the cross-

arm, the arm should be notched at points indicated by N to prevent the guard from slipping off. A guard of another type is shown in Fig. 124. These guards consist merely of pieces of strap iron securely bolted to the crossarm. Guard irons should always be of sufficient strength that there will be no possibility of their being displaced by the conductors which they are supposed to restrain.

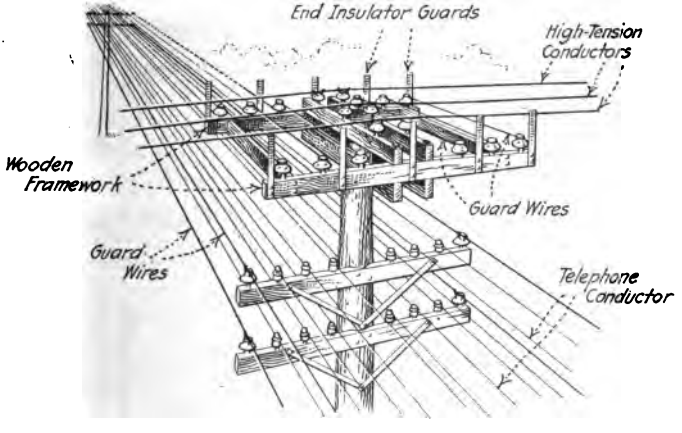


FIG. 124.—Illustrating "Joint-pole" construction at a high-tension crossing.

A transposition insulator may be used for dead-ending a line at a high-tension crossing as shown in Fig. 123, *II*. Where the wires are dead-ended as shown the possibility of a cross between the wires carried on the transposition insulator and those on crossarms below is minimized. If, instead of a transposition insulator being used at C, an insulator of the ordinary type were employed, and the wire broke some place to the right of B, for instance, the weight of the cross-over span A might pull the whole section to the left of the break back through the tie wire on the insulator and it might fall down and make contact with the wires under A. Obviously, where the wires are dead-ended on a transposition insulator as shown, there is no likelihood of their pulling through the tie and becoming fouled with the conductors below the cross-over span A.

13*d*. ¶*II*. 1. CONSTANT-POTENTIAL POLE LINES, OVER 5,000 VOLTS. One of the following forms of construction must then be adopted:—

The height and length of the cross-over span may be made such that the shortest distance between the lower cross-arms of the upper line and any wire of the lower line will be greater than the length of the cross-over span, so that a wire breaking near one of the upper pins would not be long enough to reach any wire of the lower line. The high-pressure wires should preferably be above the other wires.

Where a pole line carrying a pressure of 5,000 volts or above crosses another line, it is desirable that the heights of the poles at the crossing be so selected that crosses between the two lines will be impossible. For example, as shown in Fig. 125, if the poles carrying the

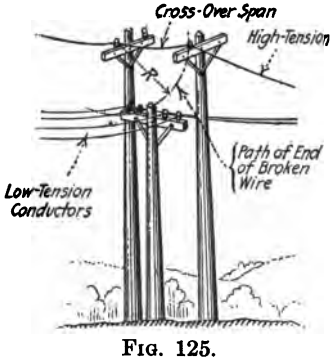


FIG. 125.

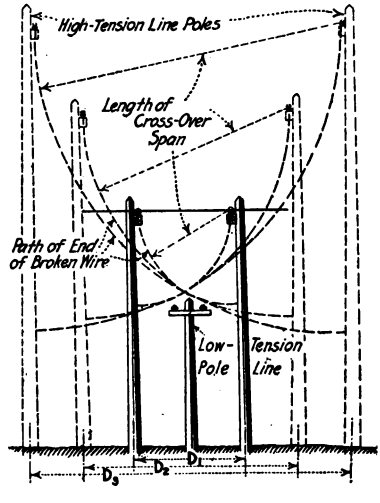


FIG. 126.

FIG. 125.—Showing how a broken cross-over-span wire of a high tension line may foul with the conductors of a low-tension line unless the high-tension poles at the crossing are sufficiently high.

FIG. 126.—Showing how the high-tension poles should increase in height as the distance between them and the low-tension line increases.

high-tension conductors, which should preferably be located above the low-tension conductors, are not sufficiently high and not sufficiently close to the low-tension line, a wire breaking in the cross-over span may drop down as shown and foul with the low-tension line. Fig. 126 indicates that if the high-tension poles are high enough, it will be im-

possible for a broken high-tension wire of the cross-over span to fall down against the low-tension conductors. It is obvious from the illustration that the farther away from the low-tension line the high-tension poles are located, the higher the high-tension poles must be to satisfy this requirement. In fact, if the high-tension poles are located very far away from the low-tension line their height becomes excessive and their cost therefore exorbitant and out of all proportion to their value. It follows then that, as a general proposition, the two poles carrying the high-tension line over a low-tension line should be set as close as possible to the low-tension line. See the author's AMERICAN ELECTRICIANS' HANDBOOK for further information on line construction.

A good method of arranging a high-tension crossing is that pictured in Fig. 127, where one high-tension pole is set very

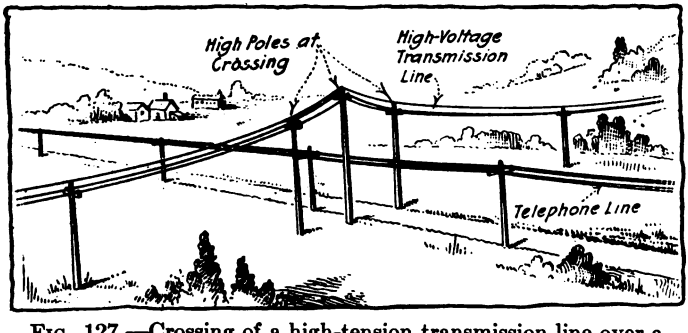


FIG. 127.—Crossing of a high-tension transmission line over a telephone line.

close to, or possibly in between, the low-tension conductors. Then somewhat shorter high-tension poles can be located on either side of the low-tension line and a reasonable distance away from it. Note that end-insulator guards as shown in Fig. 123, should be arranged on the high-tension poles adjacent to the high-tension crossing. Also note that the cross-over span for the low-tension conductors should be dead-ended on transposition insulators as shown in Fig. 123 *II*, or arranged in accordance with some other method that will provide equivalent protection. Probably the most satisfactory method

of making a cross-over on a high-tension line is one similar to that suggested in Fig. 124, on a preceding page, wherein a joint pole for both lines is used.

13*d*. ¶*II*. 2. CONSTANT-POTENTIAL POLE LINES, OVER 5,000 VOLTS. A joint pole may be erected at the crossing point, the high-pressure wires being supported on this pole at least three feet above the other wires. Mechanical guards or supports must then be provided, so that in case of the breaking of any upper wire, it will be impossible for it to come into contact with any of the lower wires.

13*d*. ¶*II*. 2. NOTE.—CONSTANT-POTENTIAL POLE LINES, OVER 5,000 VOLTS. Such liability of contact may be prevented by the use of suspension wires, similar to those employed for suspending aerial telephone cables, which will prevent the high-pressure wires from falling, in case they break. The suspension wire should be supported on high-potential insulators, should have ample mechanical strength, and should be carried over the high-pressure wires for one span on each side of the joint pole, or where suspension wires are not desired guard wires may be carried above and below the lower wires for one span on each side of the joint pole, and so spread that a falling high-pressure wire would be held out of contact with the lower wires.

Such guard wires should be supported on high-potential insulators, or should be grounded. When grounded, they must be of such size, and so connected and earthed, that they can surely carry to ground any current which may be delivered by any of the high-pressure wires. Further, the construction must be such that the guard wires will not be destroyed by any arcing at the point of contact likely to occur under the conditions existing.

A joint pole crossing is illustrated in Fig. 124, which shows the high-tension conductors of a three-phase line crossing a telephone line. The construction carrying and associated with the high-tension conductors should be very strong. End-insulator guards of same type (see Figs. 123 *I* and 124) should be used to prevent the high-tension wires from slipping accidently from the ends of the crossarms. Although a 3-ft. spacing between the high- and low-tension conductors is considered permissible in some cases, it is believed better practice to make this spacing at least 5 ft. In the illustration the guard wires on the telephone crossarms are supported on high-tension insulators about 1 ft. from the telephone wires and about 4 in. above them. These guard wires should, preferably, be grounded. Inasmuch as the guard wires on the high-tension crossarms of Fig. 124 lie directly over the guard wires on the lower crossarms, it would be impossible for one of the high-tension wires, if it broke, to contact with the telephone conductors. The end-insulator guards extend about 8 in. above the horizontal plane of the high-tension conductors.

Where the guard wires are grounded it is not necessary to support them on high-tension insulators. Where metal poles are used for high-tension crossings, and they are probably preferable except that they are much more expensive, the metal pole should be thoroughly grounded.

13*d*. ¶*II*. 3. CONSTANT-POTENTIAL POLE LINES, OVER 5,000 VOLTS. Whenever neither of the above methods is feasible, a screen of wire should be interposed between the lines at the cross-over. This screen should be supported on high tension insulators or grounded, and should be of such construction and strength as to prevent the upper wires from coming into contact with the lower ones.

13*d*. ¶*II*. 3. NOTE.—CONSTANT-POTENTIAL POLE LINES, OVER 5,000 VOLTS. If the screen is grounded each wire of the screen must be of such size and so connected and earthed that it can surely carry to ground any current which may be delivered by any of the high-pressure wires. Further, the construction must be such that the wires of screen will not be destroyed by any arcing at the point of contact likely to occur under the conditions existing.

13*e*. ¶*I*. CONSTANT-POTENTIAL POLE LINES, OVER 5,000 VOLTS. When it is necessary to carry such lines near buildings, they must be at such height and distance from the building as not to interfere with firemen in event of fire; therefore, if within 25 feet of a building, they must be carried at a height not less than that of the front cornice, and the height must be greater than that of the cornice, as the wires come nearer to the building in accordance with the following table:—

Distance of wire from building, feet	Elevation of wire above cornice of building, feet	Distance of wire from building, feet	Elevation of wire above cornice of building, feet
25	0	10	6
20	2	5	8
15	4	2½	9

13*e*. NOTE.—CONSTANT-POTENTIAL POLE LINES, OVER 5,000 VOLTS. It is evident that where the roof of the building continues nearly in line with the walls, as in Mansard roofs, the height and distance of the line must be reckoned from some part of the roof instead of from the cornice.

When lines carrying pressures of 5,000 volts or above are carried near buildings they should be arranged in accordance with the requirements indicated in Fig. 128. The intent of these requirements is to so locate the high-tension conductors that they will not interfere with the fighting of a fire in the adjacent building. That is, they should be so located that the

firemen in the street can play a stream of water on the burning structure without its striking the high-tension conductors. Where the building has a flat roof, as shown in the full lines in Fig. 128, *II*, the high-tension conductor nearest the building may be located in accordance with the dimensions, *A*, given from the farthest extending point on the cornice. But if the building has a mansard roof, as indicated by the dotted lines, then it is obvious that conductors located as just above suggested would interfere with the operations of the firemen. Then, with a mansard roof or any roof that has a slight pitch, the conductors should be located in accordance with dimen-

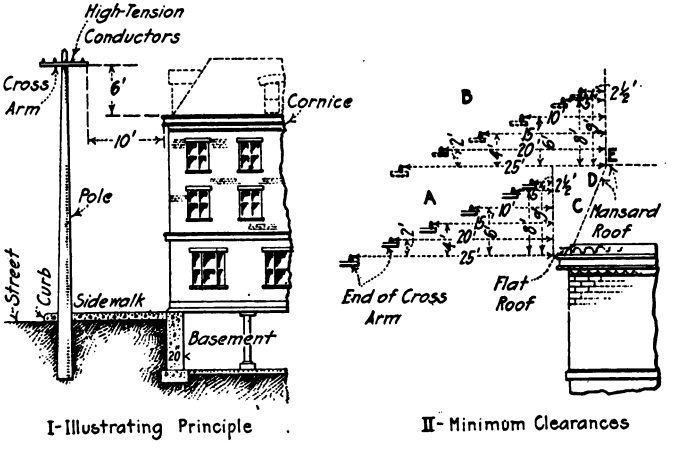


FIG. 128.—Showing minimum clearances allowable between high-voltage conductors and buildings.

sions, *B*, measured, not from the actual cornice of the building, but from what in this case is equivalent to the cornice, that is, from some point, *C* or *D* of the roof, or preferably *E*, the top corner of the building.

14. TRANSFORMERS.

(*See also Nos.* 11, 15, 36 *and* 45. *For construction rules see No.* 81.)

NOTE that the requirements of this *Rule* 14 relate only to transformers installed out-of-doors. See the note under the heading of *Rule* 11 for a list of the different sections of the

Code which specify methods of transformer installation and construction.

14. NOTE.—TRANSFORMERS. Where transformers are to be connected to high-voltage circuits, it is necessary in many cases, for best protection to life and property, that the secondary system be permanently grounded, and provision should be made for it when the transformers are built.

The ground connection to a transformer secondary winding may be, and usually is, in practice, made to one of the second-

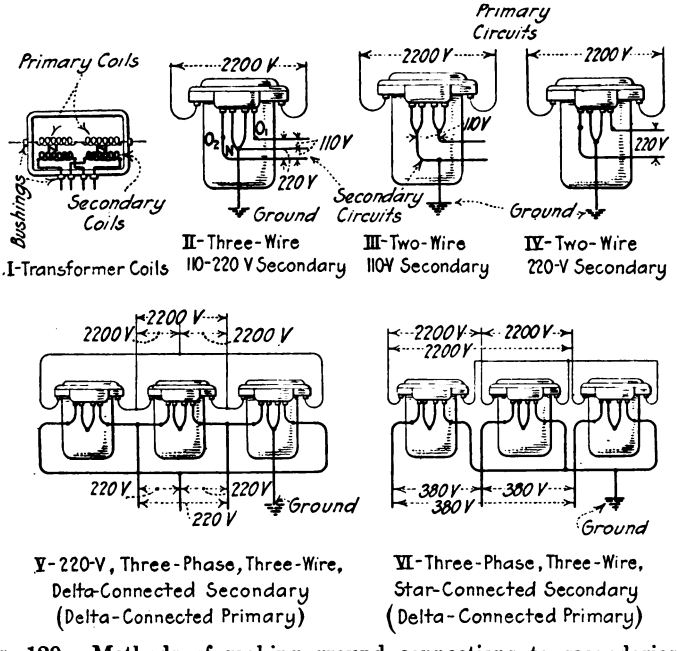


FIG. 129.—Methods of making ground connections to secondaries of standard distributing transformers.

ary conductors outside of the transformer case. Fig. 129 shows the usual methods of making such connections. There does not appear to be any particular advantage in making any special provision for the grounding of a secondary circuit of a standard single-phase distributing transformer when the transformer is built, inasmuch as such a connection can always be readily made. However, when two-phase or three-phase transformers are constructed, it may be advisable to then have

a special tap brought out from the neutral or some other point of the secondary windings.

NOTE.—Transformers connecting only to high-tension circuits (above 550 volts), as specified in the above rule, need not have their secondaries grounded. However, the secondaries of low-voltage distributing transformers where the pressure between any live wire and ground does not exceed 150 volts must be grounded; where the pressure exceeds 150 volts they may be grounded all as outlined in *Rule* 15*b*.

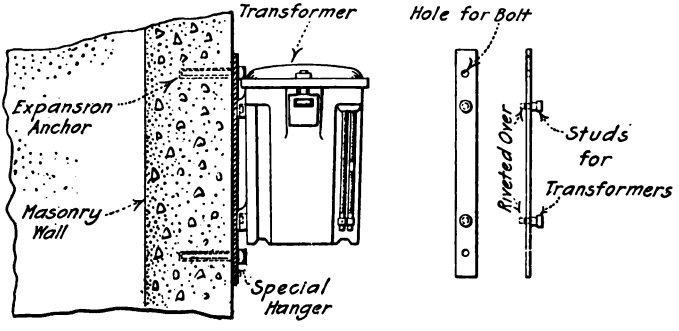
14. ¶*I*. TRANSFORMERS. Must not be attached to any building when the potential exceeds 550 volts, except by special permission, and when attached to buildings must be separated therefrom by substantial supports.

Transformers operating at pressures in excess of 550 volts should not be supported on buildings for the reason that they are likely to materially interfere with the fighting of a fire in the building and that they introduce the possibility of voltages, greater than those for which interior conducting systems are ordinarily designed, being impressed upon the circuits within the building. The preferable arrangement is always to have the transformers mounted directly on poles, on platforms built between poles, or in underground transformer vaults. The transformer should be located a reasonable distance (20 to 25 ft., if possible) away from the building. This will insure that the high-tension conductors to the transformer will be at least 20 or 25 ft. away from the building. Where it is absolutely imperative that transformers operating at pressures exceeding 550 volts be attached to buildings, they should be supported thereon by a method similar to one of those suggested below.

In arranging the supports for a transformer on a building wall it should be remembered that the transformer imposes not only a vertical stress on the wall and its supports, but also an outward stress tending to pull the upper supporting bolts out of the wall or to pull the upper timbers away from it. It is this "tipping" stress that must be considered most carefully because almost any reasonable arrangement will support the vertical stress. With an old masonry wall or a weak frame (wood) one, the only method of effectually supporting this

tipping stress is to use bolts extending clear through the wall for holding the transformer or the frame which supports it.

Methods of supporting transformers on buildings are shown in Figs. 130 and 131. Where the transformers operate at



I- Transformer Installed II- Detail of Hanger

FIG. 130.—Transformer mounted on masonry wall on special hanger.

pressures not exceeding 550 volts there is no particular objection to mounting them on buildings as shown, but where the pressure on the transformer does exceed 550 volts the practice is, as above suggested, objectionable and special permission from the local underwriters' inspector should be secured before the transformers are thus mounted. In any case, the transformer cases should not rest directly against the building wall, but should be separated therefrom in some way so that an air space will be provided between the transformer and the wall.

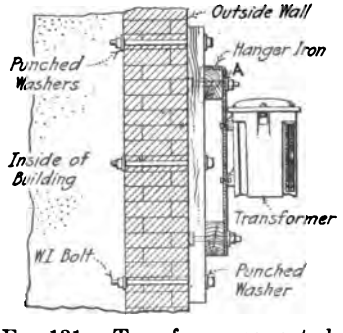


FIG. 131.—Transformer mounted on brick wall on wooden rack.

The method of supporting a transformer on a special wall hanger is shown in Fig. 130. With this arrangement, a special iron hanger, detailed in *II*, is used. If the building walls are of masonry, the hanger irons may be secured thereto with

expansion bolts, or preferably with machine bolts passing entirely through the wall. If the wall is of wooden construction, the hanger may be fastened to the wall with lag screws, but preferably with through bolts.

The method of supporting a transformer on a timber frame is shown in Fig. 131. The frame should be of substantial construction and thoroughly painted to prevent the absorption of moisture. The cross timber *A* may be made of the same proportions as a standard crossarm so that it will accommodate the crossarm hanger iron ordinarily furnished with transformers. Through bolts should be used where possible for fastening the timbers to the wall, but lag screws or expansion bolts can be utilized, where the application of through bolts is not feasible and where the wall material is strong enough to sustain the lag screws or expansion bolts.

15. GROUNDING LOW-POTENTIAL CIRCUITS.

15. NOTE.—GROUNDING LOW-POTENTIAL CIRCUITS. The grounding of low-potential circuits under the following regulations is only allowed when such circuits are so arranged that under normal conditions of service there will be no appreciable passage of current over the ground wire.

DIRECT-CURRENT THREE-WIRE SYSTEMS.

15*a*. ¶*I*. GROUNDING LOW-POTENTIAL CIRCUITS. Neutral wire must (except where supplied from private industrial power or light-

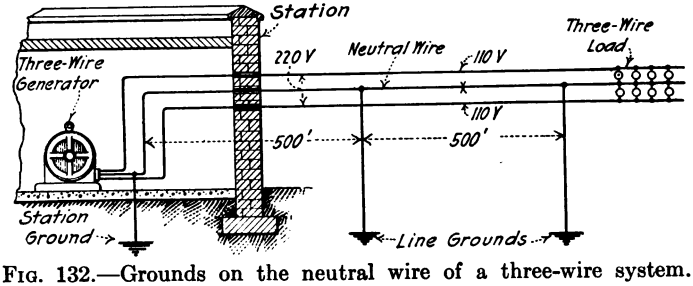


FIG. 132.—Grounds on the neutral wire of a three-wire system.

ing plants where the primary voltage does not exceed 550 volts) be grounded, and the following rules must be complied with:—

1. Must be permanently and effectively grounded at the Central Station. The ground connection must include all available underground complete metallic piping systems.

2. In underground systems the neutral wire must also be grounded at each distributing box through the box, or on the individual service as provided in sections *c* to *g* inclusive.

3. In overhead systems the neutral wire must be grounded every 500 feet, as provided in Sections *c* to *g*.

The neutral of a three-wire overhead distributing system should be grounded at least every 500 ft., as shown in Figs. 132 and 133. These conductors should be grounded because of the same reasons (outlined in a following paragraph under *Rule* 15*b*) that all secondary circuits of transformers should be grounded, namely, to tend to prevent a difference of potential greater than that for which the apparatus feeding from the

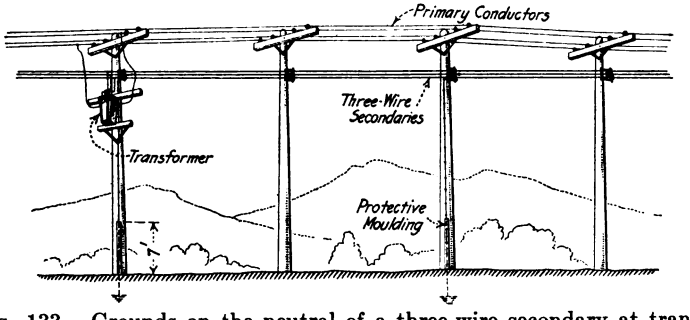


FIG. 133.—Grounds on the neutral of a three-wire secondary at transformer and along pole line.

conductors of the three-wire circuit were designed being impressed on them.

ALTERNATING-CURRENT SECONDARY SYSTEMS.

15*b*. ¶*1*. GROUNDING LOW-POTENTIAL CIRCUITS. Transformer secondaries of distributing systems (except where supplied from private industrial power or lighting plants where the primary voltage does not exceed 550 volts) must be grounded, provided the maximum difference of potential between the grounded point and any other point in the circuit does not exceed 150 volts and may be grounded when the maximum difference of potential between the grounded point and any other point in the circuit exceeds 150 volts. In either case the following rules must be complied with:—

1. The grounding must be made at the neutral point or wire, whenever a neutral point or wire is accessible.

2. When no neutral point or wire is accessible, one side of the secondary circuit must be grounded.

3. The ground connection must be at the transformers or on the individual service as provided in Sections *c* to *g*, inclusive, and when transformers feed systems with a neutral wire, the neutral wire must also be grounded at least every 500 feet.

The ground connections to transformer secondaries may be made as shown in Fig. 129. The arrangement of the primary and secondary windings within a distributing transformer is indicated in *I*. There are usually two primary and two secondary coils. The transformer may be adapted for different primary and secondary voltages by connecting these coils either in series or in parallel. The series or parallel connections of the secondary coils are usually made by suitably joining the secondary conductors outside of the transformer. The primary coils may be connected in series or in parallel by means of a connection block and straps provided within the transformer.

The ground connection on a transformer three-wire secondary operating at 110 and 220 volts is made as shown in Fig. 129 at *II*. The ground is connected to the neutral point of the secondary and to the neutral wire.

The ground connection on a transformer two-wire secondary operating at 110 volts is made as indicated in Fig. 129 at *III*. Inasmuch as it would be infeasible to join to the neutral point of a transformer secondary winding, which is connected as at *III*, the earth connection is made to one side wire of the circuit. To connect to the true neutral in this case it would be necessary to tap a lead to points *N* and *N* of the two secondary coils as indicated at *I* and then to carry this lead to ground. Obviously, this could not be done with distributing transformers of ordinary construction without dismantling and re-winding the transformer.

The ground connection of a transformer two-wire secondary operating at 220 volts may be made as diagrammed in Fig. 129 at *IV*. In this case the ground wire joins the secondary winding at its neutral point.

Three-phase transformer secondaries may be grounded as shown at *V* and *VI*, Fig. 129. With the delta-connected

secondary of *V*, the ground is not at the neutral point of the secondaries of the group and it is impossible to connect the ground wire to the true neutral point of a three-phase delta-connected group, unless an artificial neutral point be established through the insulation of three resistors or similar devices connected in star. The star-connected secondaries of *VI* are grounded at the true neutral point on the secondary system.

Why it is desirable to ground transformer secondaries may be explained thus: If, through accident, the primary and secondary coils of a transformer become electrically connected, the high-tension primary voltage is then impressed upon the normally low-tension secondary circuit. Any person then touching any conducting component of the secondary system would have impressed on him to ground the primary voltage. Furthermore, if the primary and secondary are in electrical contact, the fire hazard is greatly increased because then the high-tension voltage (possibly 2,200 volts) is impressed between the secondary system and ground.

Now the entire secondary system and its conductors, fittings and appliances are ordinarily insulated for a voltage of only 110 or 220. It follows that the 2,200-volt pressure is likely to break down this 110- or 220-volt insulation, and impel a current through the insulation to ground and possibly produce a fire, by causing arcs between the conductors and the interior water or gas piping or other grounded metal, or in low-voltage fittings. If the secondary of the transformer is grounded a voltage between the secondary system and ground that would be dangerous to life, cannot, except under unusual conditions, exist.

EXAMPLE.—Consider the diagram of Fig. 134 which shows a generator feeding a secondary distribution system through a transformer. Note that there is normally no electrical connection between the primary and secondary circuits. The connection *C* shown is an accidental cross between the high- and low-tension circuits which might be within the transformer case, or at some point out on the line as shown at *C* in Fig. 135. The primary voltage is assumed to be 2,200, and the secondary voltage 110. Now assume further that there is no ground on the low-tension or secondary circuit, but that there is a ground

at G on one of the primary or high-tension conductors. This ground G (Figs. 134 and 135) might be an accidental ground, such as a tree ground, or it might be a permanent ground placed for some reason or other on the primary circuit.

Now with conditions as above defined, a man, M, Fig. 134, standing on the earth and touching any live current-carrying

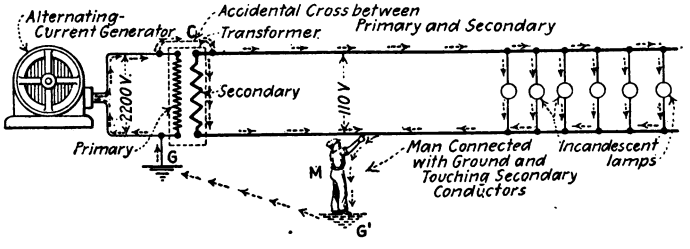


FIG. 134.—Showing how a person may receive a shock by touching an ungrounded secondary circuit which is "crossed" with a primary circuit.

part of the secondary circuit, would have impressed across him, between the part of his body that touched the circuit and ground, 2,200 volts. This pressure would, probably, force through the man's body, as shown by the full arrows, a current sufficiently great to kill him.

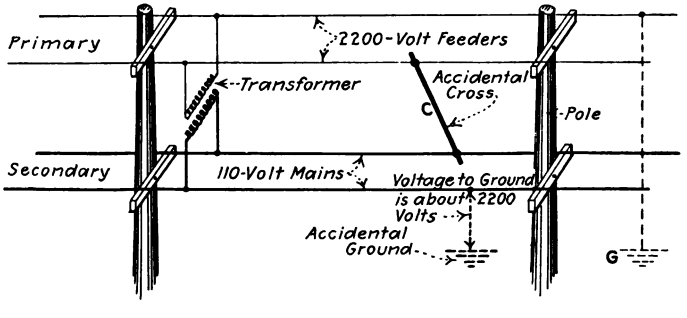


FIG. 135.—Accidental cross between high-voltage primary feeder and low-voltage secondary mains—no permanent ground on secondary.

But, if the secondary circuit be grounded by connecting it to the permanent ground PG, Figs. 136 and 137, then the maximum voltage that could then exist (except under very unusual conditions) between the secondary circuit and ground is 55 volts. For example: An accidental cross occurs between

the primary and secondary circuits either out on the pole line as shown in Fig. 136 or within the transformer case (Fig. 137). A current of considerable intensity will be forced through the cross and the permanent ground as shown in Fig. 137 by the arrows. In other words, the permanent ground provides a short-circuit path for the current, and an excessive current

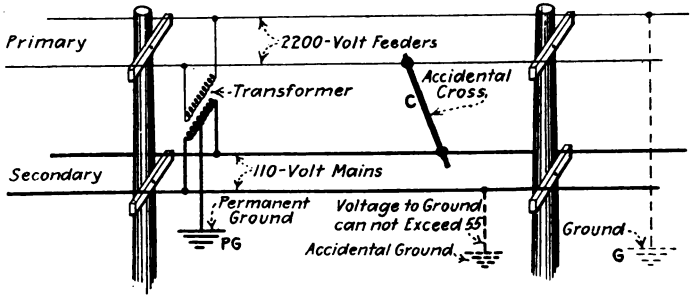


FIG. 136.—Transformer secondary permanently grounded. Accidental cross between primary and secondary line wires.

will flow. This will cause a fuse or a circuit-breaker, located in the high-tension or primary circuit at the station or distribution center to open, whereby the primary circuit will be disconnected from its source of energy.

The automatic cut-out just referred to may be either the primary fuses at the transformer, inserted between the pri-

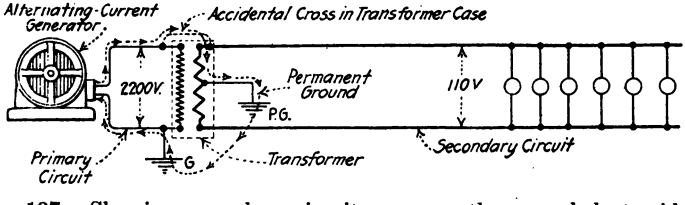


FIG. 137.—Showing secondary circuit permanently grounded at middle point of transformer secondary winding.

mary main and the transformer, the fuses at a high-tension distribution center or the fuses or circuit-breaker protecting the high-tension circuit at the central station. Furthermore, the permanent ground placed on a secondary circuit tends to form a short-circuit or shunt path of very low resistance be-

tween the secondary circuit and ground. Then in case the high-tension circuit does accidentally contact with the low-tension circuit and a person now touches the low-tension circuit, the secondary ground connection constitutes a short-circuit path around him and thereby prevents him from being "shocked."

For maximum protection the primary circuit must be provided with automatic cut-outs (fuses or circuit-breakers) so that in case of a cross between the primary and secondary, like that just referred to, there will be every assurance that the excessive current flowing through the secondary-circuit ground connection will cause the automatic cut-out to open and disconnect the transformer primary or the primary circuit from its source of energy.

The reason for connecting the ground wire to the middle or neutral point of a transformer secondary is that where this is done the difference of potential then possible between any part of the secondary circuit and ground is a minimum.

EXAMPLE.—If the ground connection is made at the middle point of a transformer secondary connected for 220 volts as shown in Fig. 129, *II*, then the maximum possible difference of potential between any part of the secondary circuit and ground is, except under very unusual conditions, 110 volts. If, instead of the ground wire having been connected at N (*II*) it were connected to either of the outside wires at O_1 or O_2, then the maximum possible difference of potential between parts of the circuit and ground would be 220 volts.

A cross between a high-tension primary circuit and a low-tension secondary circuit may be dangerous even if there is no ground on the primary circuit. It is sometimes supposed that there is no danger in touching one side of a high-tension circuit if the other side of the circuit is free from grounds. This view is erroneous, and it is quite possible for a person standing on or in electrical connection with ground to be killed by touching at one point a high-tension circuit upon which there are no other grounds or by touching a low-tension circuit which is in accidental contact with such a high-tension circuit. If the high-tension circuit connects with an extensive network, this

network will then have considerable electrostatic capacity (permittance) against ground. The short-circuit path, comprising in series the condenser thus provided and the person, may have such low impedance that it will in many cases permit a charging current to flow which is sufficient, if it passes through a person's body to ground, to kill the person. Grounding the low-tension circuit will eliminate the life hazard above described that may be present because of the electrostatic capacity of an ungrounded primary circuit which is in contact with a secondary circuit.

The objections to grounding a low-tension secondary system are: (1) *A single accidental ground upon one of the secondary conductors, if the secondary conductor of opposite polarity is permanently grounded, may, and probably will, interfere with the service.* (2) *With permanent ground on a secondary circuit, if the ground wire connects to one of the outside wires of the secondary circuit, there then exists between the other wire of the circuit (that is, the conductor of opposite polarity) and ground the full difference of potential of the secondary circuit.* (3) *Permanent grounds on secondary circuits may cause difficulties when tests are being made.* (4) *Permanent grounds increase the expense of installation.* It is apparent then that there are certain disadvantages to secondary grounding.

It is generally conceded that secondary grounding tends to increase rather than decrease the fire hazard. For example: With one side of the secondary permanently grounded, one accidental ground or breakdown of insulation on the other side of the circuit will involve a short-circuit and possibly a fire if the overload protection of the circuit does not act promptly. Obviously, when a secondary system is entirely free from grounds, two breakdowns or accidental grounds, one on each side of the system, that is, one on the positive wire and one on the negative wire, are necessary to constitute a short-circuit. Where ground detectors are installed, the first ground will ordinarily be discovered and cleared before the second one occurs. However, in spite of the above disadvantages, which practice has shown to be relatively unimportant, it is now considered the best practice to ground all secondary circuits so that life

hazard will be a minimum. This course is recommended by practically all competent authorities, particularly where the high-tension voltage exceeds 550.

Secondary grounds should be tested periodically—about once a year—to insure that they are effective. It is especially important that the ground connection be tested where the transformer is located a considerable distance from the buildings served by its secondaries. It sometimes occurs that a secondary ground connection is effective in preventing potential rises on the secondary system only within a relatively limited area. Such conditions are attributed to the poor conducting properties of the earth adjacent to the ground on the secondary system.

The grounding of a neutral wire of a three-wire system not only tends to decrease life hazard but it also tends to insure the continuity of the neutral conductor, because if the neutral is grounded at frequent intervals along its length and it breaks at some point, the neutral conducting path will be completed around the break through the two grounds on either side of it.

The general situation relative to grounding may be outlined thus: While the CODE specifies no requirements one way or the other as regards the grounding of the neutral on a high-potential system (550 to 3,500 volts) it specifies (*Rule* 5) that lightning arresters must be installed on circuits operating at these voltages. Grounding, it appears, is regarded as a medium of reducing the risk of shock or injury to persons, but which tends to increase fire hazard; hence in compiling the rules now in effect the Electrical Committee yielded to the "life hazard" plea (*Rule* 15*b*) only for circuits operating at pressures not exceeding 150 volts. That is, grounding the transformer secondaries of circuits operating at pressures of 150 volts and below is compulsory, except where a system is supplied from private industrial power or lighting plants where

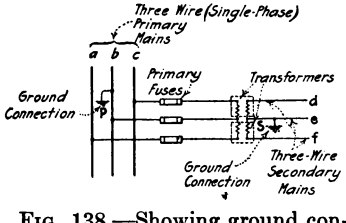


FIG. 138.—Showing ground connections on both primary and secondary sides of transformer.

the primary voltage does not exceed 550. This in effect means that all circuits used for domestic and business electric lighting and service must be grounded. For circuits with voltages above 150 grounding is optional as far as the CODE is concerned, but in practice nearly all of the secondary circuits, except those operating at rather high voltages, are grounded. For example: In Fig. 138 the ground connection *S* on the 110–220-volt three-wire secondary is compulsory, while that at *P* on the high-tension (above 550 volts) mains is optional.

GROUND CONNECTIONS.

15*c*. ¶*I*. GROUNDING LOW-POTENTIAL CIRCUITS. GROUND CONNECTIONS. When the ground connection is inside of any building, or the ground wire is inside of, or attached to any building (except Central or Sub-stations), the ground wire must be of copper and have an approved rubber-insulating covering National Electrical Code Standard, for from 0 to 600 volts.

Rubber-insulated, copper ground wires should be used in or on buildings because in these locations maximum conductivity and high insulation are desirable so that a fire risk may be decreased to a minimum. Under extreme conditions ground wires may carry large currents. Iron ground wires cleated directly to the pole as shown in Fig. 139 have been found satisfactory in aerial construction, but they should be inspected frequently because an iron ground wire is subject to corrosion, particularly at the ground line. Obviously, every precaution should be observed in order to maintain the ground wires intact.

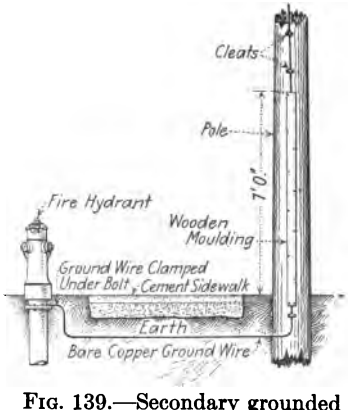


FIG. 139.—Secondary grounded on fire hydrant.

15*d*. ¶*I*. GROUNDING LOW-POTENTIAL CIRCUITS. GROUND CONNECTIONS. The ground wire in direct-current three-wire systems must not at Central Stations be smaller than the neutral wire and not smaller than No. 6 B. & S. gage elsewhere. The ground wire in alternating-current systems must never be less than No. 6 B. & S. gage.

No ground wire should ever be smaller than No. 6, A. W. G. (A. W. G. means American Wire Gage, which is the same as the B. & S. Gage), because wires smaller than this are too weak mechanically to insure against their breakage due to mechanical injury in the exposed conditions in which they are frequently installed.

15*d*. ¶*II*. GROUNDING LOW-POTENTIAL CIRCUITS GROUND CONNECTIONS. On three-phase systems, the ground wire must have a carrying capacity equal to that of any one of the three mains.

15*e*. ¶*I*. GROUNDING LOW-POTENTIAL CIRCUITS. GROUND CONNECTIONS. The ground wire must, except for Central Stations and transformer sub-stations, be kept outside of buildings as far as practicable, but may be directly attached to the building or pole by cleats or straps or on porcelain knobs. Staples must never be used. The wire must be carried in as nearly a straight line as practicable, avoiding kinks, coils and sharp bends, and must be protected when exposed to mechanical injury.

Ground wires for central stations, substations and on aerial pole lines are ordinarily of bare wire. Insulated wire should (*Rule* 15*c*, ¶*I*) be used for ground connections in all ordinary buildings. The ground wires are held to the walls of the building or to the pole with small pipe straps. Staples should not be used because in driving them they are likely to nick the wire, rendering it liable to breakage. Furthermore, the staples may be driven in too far and therefore weaken the wire or shear it partially asunder. Heavy galvanized iron wire, preferably stranded wire like that used for guying, is often used for pole-line grounds but is liable to corrosion. Sharp kinks, coils or bends should not be permitted in ground wires because these tend to increase the inductance of the ground conductor which greatly increases the opposition of the conductor to high-frequency static discharges due to lightning or to surges. Fig. 139 shows a method which has been successfully used in some localities of making a pole-line ground on a fire hydrant.

15*e*. ¶*I*. NOTE.—GROUNDING LOW-POTENTIAL CIRCUITS. GROUND CONNECTIONS. This protection can be secured by use of approved conduit or moulding, and as a rule the ground wire on the outside of a building should be in conduit or moulding at all places where it is within seven feet from the ground.

The protection of ground wires against mechanical injury may be effected by running the ground wire in iron pipe or conduit, or in molding, as shown in Fig. 139. If the ground wire is protected with iron pipe or conduit and constitutes a ground for a lightning arrester the wire should be electrically connected to the pipe by soldering it thereto or by driving in a metal wedge at the top. The reason for this is that if the wire is not electrically connected to the pipe the pipe increases the inductance of the wire, but if the pipe and wire are electrically

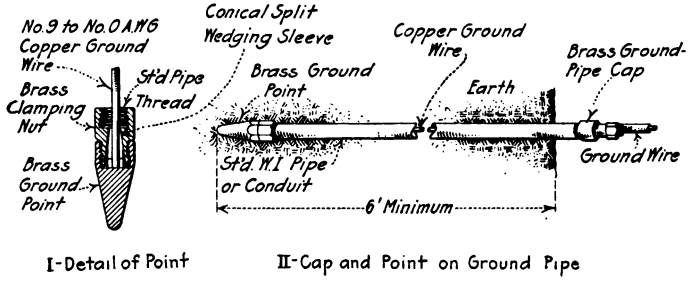


FIG. 140.—Special fittings for adapting wrought-iron pipes suitable for ground pipes.

connected together the pipe thus becomes part of the electrical path and this objection disappears. Fig. 140 illustrates a ground point and a ground cap whereby the ground wire is connected electrically to the top of the pipe by means of the special cap.

15*f*. ¶*I*. GROUNDING LOW-POTENTIAL CIRCUITS. GROUND CONNECTIONS. The ground connections for Central Stations, transformer sub-stations, and banks of transformers must be permanent and effective and must include all available underground piping systems including the lead sheaths of underground cables.

The ground connections for central stations should connect to all grounded metal work within the station so that no portion of this grounded metal work can become charged to a higher potential above ground than the other portions. If the different components are not electrically connected there is a possibility of one component attaining a higher potential than another which might cause an electric arc between

them, and a fire. Furthermore, there will be danger of an electric shock to an attendant who touches two conducting members at different potentials. Figs. 64 and 65 illustrate central-station grounding installations which interconnect all available grounded metal work.

15*g*. ¶*I*. GROUNDING LOW-POTENTIAL CIRCUITS. GROUND CONNECTIONS. For individual transformers and building services, the ground connection may be made as in Section *f*, or may be made to water piping system running into buildings.

15*g*. ¶*II*. GROUNDING LOW-POTENTIAL CIRCUITS. GROUND CONNECTIONS. With overhead service, this connection may be made by carrying the ground wire into the cellar and connecting on the street side of meters, main cocks, etc.

15*g*. ¶*III*. GROUNDING LOW-POTENTIAL CIRCUITS. GROUND CONNECTIONS. Where the service enters the cellar or basement, this connection may be made by carrying the ground wire through the cellar or basement and connecting as above.

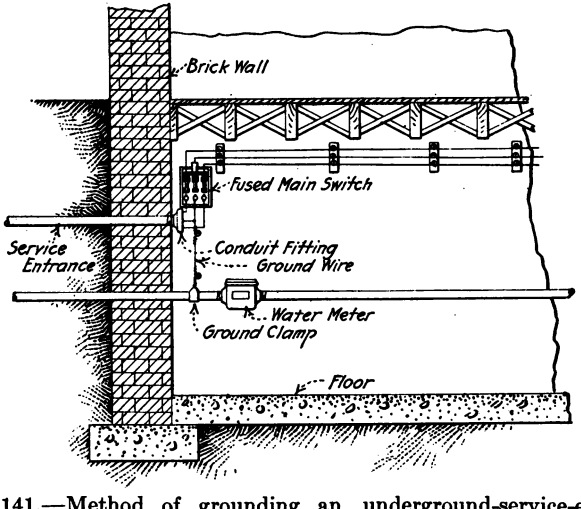


FIG. 141.—Method of grounding an underground-service-entrance neutral. (The arrangement of the switch shown above might be improved. See Fig. 201.)

The ground connection to a neutral of an underground service is shown in Fig. 141. The ground wire is connected to the water pipe on the street side of the meter, so that if the meter is removed the ground connection will remain intact.

15*g*. ¶*IV*. GROUNDING LOW-POTENTIAL CIRCUITS. GROUND CONNECTIONS. Where the ground wire is run through any part of a building, unless run in *approved* conduit, it shall be protected by porcelain bushings through walls or partitions and shall be run in *approved* moulding, except that in basements it may be supported on porcelain.

15*g*. ¶*V*. GROUNDING LOW-POTENTIAL CIRCUITS. GROUND CONNECTIONS. Connections should not be made to piping systems which have cement joints, but should only be made to complete metallic pipe systems.

Ground connections should not be made to piping systems which have cement joints because the resistance of such a piping system may be very high. In cases where the cement has fallen away from the joints in an old piping system of this character the resistance of one of the pipe joints may be so high that the joint practically constitutes an "open" in the circuit.

15*g*. ¶*V*. NOTE.—GROUNDING LOW-POTENTIAL CIRCUITS. GROUND CONNECTIONS. In connecting a ground wire to a piping system, the wire should be sweated into a lug attached to an approved clamp, and the clamp firmly bolted to the water pipe after all rust and scale have been removed; or be soldered into a brass plug and the plug forcibly screwed into a pipe fitting, or where the pipes are cast iron, into a hole tapped into the pipe itself. For large stations, where connecting to underground pipes with bell and spigot joints, it is well to connect to several lengths, as the pipe joints may be of rather high resistance.

Earth connections or connections to ground are usually made by connecting the ground lead to either: (1) *A water pipe* by means of a ground clamp, Fig. 294, or by clamping it to a plug screwed into a pipe fitting or into a hole drilled and tapped in the pipe, Fig. 142. (2) *A copper or cast-iron plate* buried in permanently damp earth or in a prepared bed, Figs. 62, 64 and 66. (3) *A metal pipe or tube* driven into the ground down into permanently moist earth, Figs. 63, 143, 144 and 145. (4) *A metal bar or stake* driven into the ground down into permanently moist earth, Fig. 155. Frequently effective ground connections can be made by joining the ground lead to flumes, penstocks (Fig. 65) or the steel rails of a railroad system.

To make a ground connection on a water pipe, an approved ground clamp (Fig. 294) should be used or a special brass plug, Fig. 147, screwed as illustrated in Fig. 142 into a tee

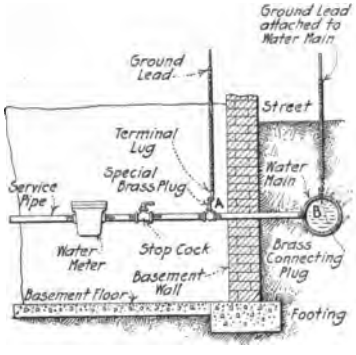


FIG. 142.—Ground connection to water pipes.

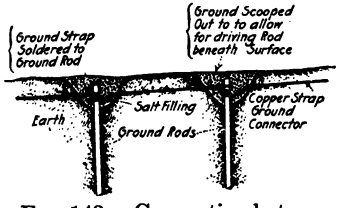


FIG. 143.—Connection between different pipes of a multiple-pipe ground.

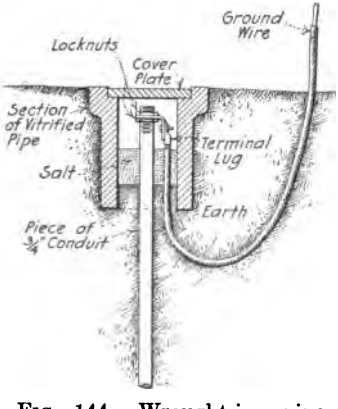


FIG. 144.—Wrought-iron-pipe ground with "salting" pocket.

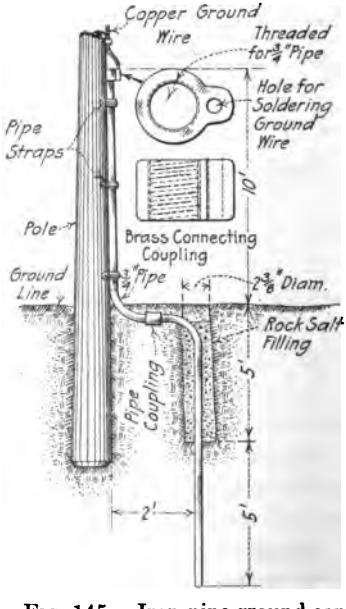


FIG. 145.—Iron-pipe ground connection with rock-salt filling around pipe.

fitting in the water pipe as shown at *A*, or into a hole drilled and tapped into the water pipe itself as at *B*. Sometimes the ground wire is soldered directly to the ground pipe as shown in Fig. 146. It is obviously desirable to make the connection in the water main as at *B*, where possible, but where this is not feasible it may be made in a service pipe which leads directly to the water main as shown at *A*. The connection should always be made on the street side of the water meter. This provides probably the best and most effective ground connection where an extensive pipe system is available. In important installations, such as the ground connection for a central station, the ground lead should be connected to the piping system at several different points as shown in Fig. 64.

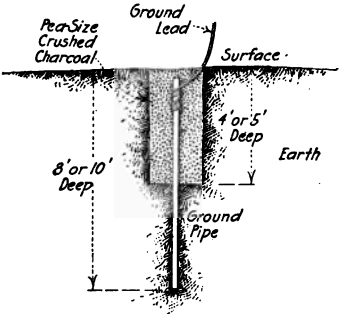


FIG. 146.—Showing a ground rod of pipe with charcoal packing around it.

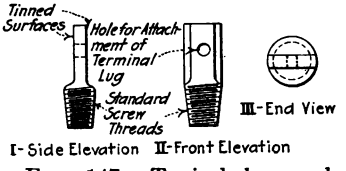


FIG. 147.—Typical brass plug for connecting ground leads to water pipes.

15*g*. ¶*V*. NOTE (*Con't.*).—GROUNDING LOW-POTENTIAL CIRCUITS. GROUND CONNECTIONS. Where ground plates are used, a No. 16 Stubbs' gage copper plate, about three by six feet in size, with about two feet of crushed coke or charcoal, about pea size, both under and over it, would make a ground of sufficient capacity for a moderate-sized station, and would probably answer for the ordinary sub-station or bank of transformers. For a large central station, a plate with considerably more area might be necessary, depending upon the other underground connections available. The ground wire should be rivetted to the plate in a number of places, and soldered for its whole length. Perhaps even better than a copper plate is a cast-iron plate with projecting forks, the idea of the fork being to distribute the connection to the ground over a fairly broad area, and to give a large surface contact. The ground wire can probably best be connected to such a cast-iron plate by soldering it into brass plugs screwed into holes tapped in the plate. In all cases, the joint between the plate and the ground wire should be thoroughly protected against corrosion by painting it with water-proof paint or some equivalent.

The ground-plate method of connection is now probably the most infrequently applied of all (in spite of the fact that

it has, as shown in the following table, a very low resistance), it having been superseded to a large extent by the ground-pipe method. Typical ground-plate installations are shown in Figs. 62, 64 and 66. A ground plate should always, if possible, be buried in permanently moist soil. Where it is possible to install the plate in the earth under the bank of a stream that never runs dry, the ideal condition will be attained. Merely sinking a metallic plate in the bed of a stream, particularly if it has a rocky bottom and if the water in the stream is pure, will not necessarily make a good ground connection. Pure water, contrary to the general belief, has a very high resistance. However, if this water is combined with metallic salts that usually are in solution in the earths, the conductivity of the combination is good. While a metallic ground plate buried in crushed coke or charcoal (Fig. 62), usually has a lower resistance than the ground afforded by a single pipe driven into the earth, it is probable that a multiple pipe connection, Fig. 65, affords a better ground than one ground plate.

A charcoal or coke bed for a ground plate has the effect of increasing the area of the plate in contact with the earth because the carbon is a good conductor and the granulated carbon also acts somewhat like a sponge. It retains moisture and tends to maintain the adjacent earth in a damp condition, thereby rendering its conductivity a maximum.

The method of making a plate ground is shown in Figs. 62, 64 and 66. A hole is excavated as near as possible to the location where the ground connection is to be made. Usually the excavation should be about 6 ft. long, 4 ft. wide, and deep enough to insure to a reasonable certainty that its bottom will always lie in a permanently moist stratum. Ordinarily such holes should be at least 8 or 10 ft. deep. The bottom of the hole is filled with a 2-ft. layer of crushed charcoal or pea coke, well tamped. The ground plate is then placed on this filler and covered with another 2-ft. layer of the granulated carbon. This layer should also be tamped. The excavation is then backfilled to the surface with earth. If common salt (sodium chloride) is mixed with the backfilling, the conductivity of the earth will be increased. However, the salt will,

in time, dissolve and soak away into the earth. If the conductivity of the soil at the point where the ground is located is poor, provision should be made somewhat as suggested in Fig. 144, whereby the salt can be replenished and the high conductivity of the soil continuously maintained.

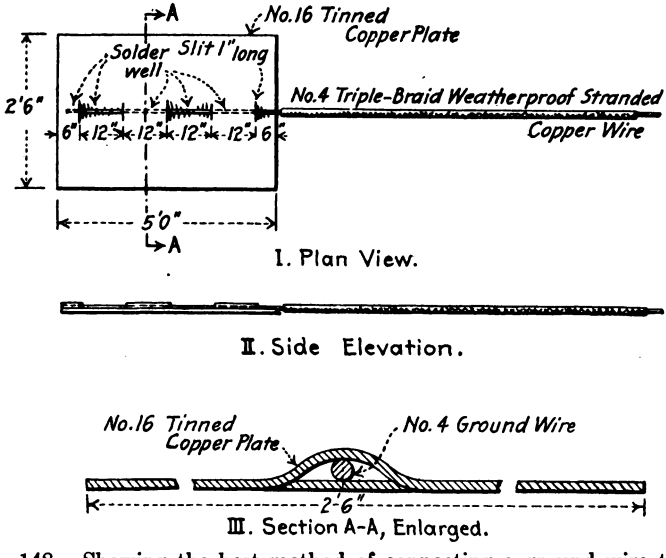


FIG. 148.—Showing the best method of connecting a ground wire to a ground plate.

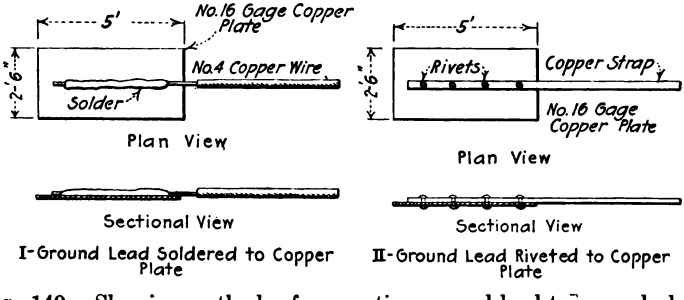


FIG. 149.—Showing methods of connecting ground lead to ground plate.

Ground plates are shown in Figs. 148 and 149. The plates are usually made of No. 14 and 16 gage (approximately $\frac{1}{16}$ in. and $\frac{1}{20}$ in. thick, respectively) sheet copper. Ribbed cast-

iron plates are, however, quite satisfactory. Commercial sheet-iron plates should not be used because the ordinary commercial "sheet iron" is usually sheet steel and will corrode rapidly and waste away entirely. A ground plate should have an area on each surface of about 10 or 12 sq. ft., that is, a total superficial area of about 20 to 24 sq. ft.

The methods of connecting the ground leads to ground plates are shown in Figs. 148 and 149. In Fig. 148 slots about 1 in. long are punched through the plate across its center line. The end of the ground wire, which has been previously stripped of its insulation and tinned, is threaded through the slots as shown and is then soldered to the plate. Both surfaces of the plate should be well tinned. The method just described is probably the best one for connecting a lead to a ground plate. The lead can be soldered to the upper face of the ground plate as shown in Fig. 149, *I*. Where a copper strap is used for a ground lead, it can be rivetted to the plate as shown in Fig. 149, *II* and then soldered.

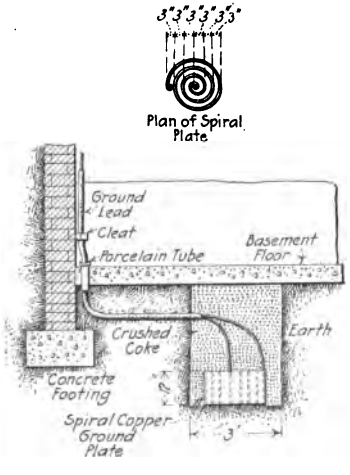


FIG. 150.—Spiral ground plate installed under a basement floor.

A spiral sheet-copper ground plate is shown in Fig. 150. Ground plates of this type have been employed to a certain extent by the telephone companies in the East, where it was desired to secure large superficial contact area within a small volume. These spiral plates are usually bedded in crushed coke or charcoal, unless the earth in which they are installed is very damp.

15g. ¶ *V*. NOTE (*Con't.*)—GROUNDING LOW-POTENTIAL CIRCUITS. GROUND CONNECTIONS. Companies and Departments in charge of water works are urged to allow the attaching of ground wires to their piping systems in the full confidence that the integrity of such piping systems will not in any way be affected whatever may be the normal voltage.

The pipe earth-connection, Fig. 143, is made by driving a piece of wrought-iron pipe into the ground to such a depth that its lower portion will penetrate permanently moist soil. The pipe connection offers the cheapest method of making a ground where it is not possible to connect to a water piping system. At the same time, experience has shown that pipe grounds are very effective if properly installed. They have, however, the disadvantage that they should be inspected at intervals because iron pipe under certain conditions rusts away rapidly particularly at the ground line. Galvanized wrought-iron conduit may be used instead of pipe for making grounds of this character.

The resistance of a pipe earth-connection varies about inversely as the depth of the pipe in the conducting stratum. Practically all of the resistance of the connection is concentrated in the immediate vicinity of the pipe. When preparing multiple-pipe grounds, no two pipes of the system should be located closer together than 6 ft. Where the pipes are thus spaced the combined resistance of a multiple-pipe ground will vary inversely as the number of pipes composing it, that is, a two-pipe earth-connection will have one-half the resistance of a one-pipe connection, and eight pipes will have one-eighth the resistance of one pipe. The diameter of the pipe has, within reasonable limits, very little effect one way or other on the resistance of the ground. A 2-in. pipe ground will probably have a resistance only 5 per cent. to 10 per cent. smaller than a ground made with a 1-in. pipe. A good earth-connection made by driving one pipe into the ground should have a resistance of less than 20 ohms.

The size of pipe or rod to use for making grounds is a factor which admits of no absolute determination. As elsewhere suggested, the diameter of the rod or pipe does not greatly influence the resistance of the earth-connection, one way or the other. However, the rod or pipe must always be large enough to insure ample mechanical strength and so that it will not vibrate (see a following paragraph) excessively while it is being driven. A 1-in. wrought-iron pipe is usually satisfactory, but ¾-in. and ½-in. pipe is sometimes used. In important installations, 2-in. pipe may be used.

The methods of connecting the ground lead to the ground pipe are shown in Figs. 146 and 151 to 153 inclusive. The simplest method is shown in Fig. 146, wherein the copper ground lead is twisted around the ground pipe and soldered thereto. The portion of the pipe where the lead connects, and the lead itself, must be thoroughly tinned prior to the soldering to prevent any possibility of electrolytic action.

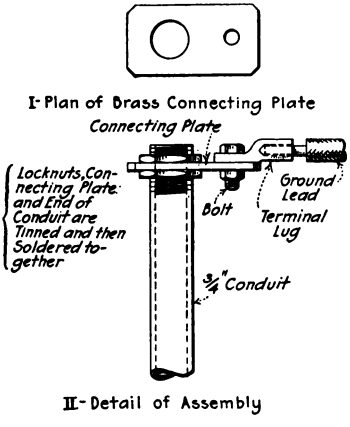


FIG. 151.—Method of connecting to ground pipe where lead taps off horizontally.

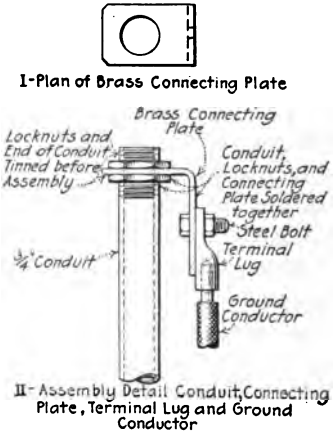


FIG. 152.—Method of connection where ground lead is vertical.

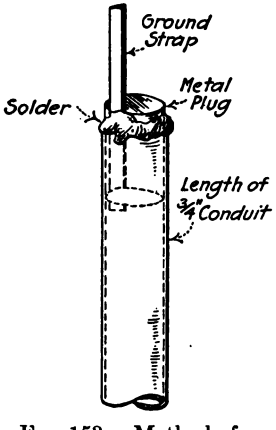


FIG. 153.—Method of connecting a ground strap to a ground pipe.

In soldering a copper wire to an iron pipe, the pipe should be filed until it is bright. It shall then be tinned by heating it, using salammoniac as a flux and applying the solder. The end of the ground wire which has been previously tinned also is then wrapped around the pipe several times, the whole heated and the solder applied.

The method of connecting a ground strap to a ground pipe is shown in Fig. 153. The strap is wedged within the pipe by a metal plug driven in the orifice. Then the plug, pipe and strap are soldered together. The ground lead can be connected to a pipe by means of a plate clamped between a couple of locknuts on the threaded end of a pipe as shown in the assembly of Fig. 144 and in the details of Figs. 151 and 152. Where the space is restricted it may be necessary to bend down the connecting plate as shown in Fig. 152, but under ordinary conditions it may be permitted to extend as shown in Fig. 151. A terminal lug soldered on the end of the ground lead provides an effective method of connection and permits the disconnection of the lead if such may be necessary for testing. All metallic parts that are thus in contact at the top of a ground pipe should be tinned to prevent electrolytic action.

Galvanized awning fittings may be used in making connections to ground pipes.

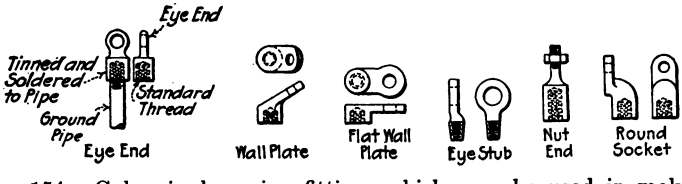


FIG. 154.—Galvanized awning fittings which may be used in making connections with ground pipes.

Some of these standard fittings are shown in Fig. 154. They can be readily procured of galvanized iron and in special cases provide convenient attachment lugs.

The distance to which to drive a ground pipe is determined to some extent by local conditions. The pipe should always go down far enough that its greater portion will always lie in permanently moist earth. As a general rule, a ground rod should be driven at least from 6 to 10 ft. into the earth and a greater penetration is often desirable.

A ground rod or pipe should not be permitted to vibrate while it is being driven. If it does vibrate, it forces away the earth that surrounds it leaving an air space between the

metal and the adjacent soil as shown in Fig. 155, greatly increasing the resistance of the ground afforded by the rod or pipe. This difficulty is most likely to occur where the soil is moist.

The earth around a ground rod should always be tamped after a rod has been driven, to correct for the vibration difficulties described above and to make the surrounding soil contact closely with the rod. That tamping will materially decrease the resistance of a ground is evident from tests (see *Electrical World*, Dec. 1, 1910, page 1295). The resistance of the earth connection afforded by a ground rod may be 20 to 40 times less after tamping than before.

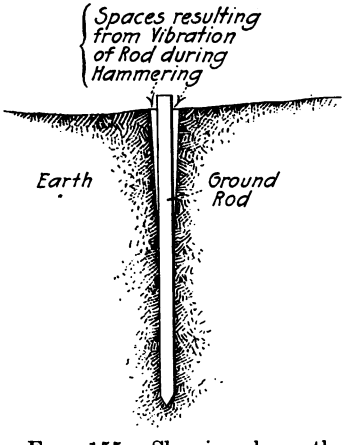


FIG. 155.—Showing how the vibration of a rod while it is being driven may decrease the area of contact of the rod with the earth.

Special points and caps for ground pipes may be purchased, whereby an ordinary length of pipe can be readily converted into a good ground pipe by screwing the *point* on its lower end and the *cap* on its upper end. With the Fargo point, illustrated in Fig. 140, the ground wire is connected to the point by the wedge action of a conical, split, steel sleeve. It is carried down within the pipe to the point, as shown in the illustration. The provision of a point on the lower end of a pipe renders it easy to drive. A cap at the upper end of the pipe prevents the entrance of moisture and also effects an electrical connection between the ground wire and the pipe.

Ground-pipe point and cap castings as supplied by the Westinghouse Electric & Manufacturing Company are shown in Fig. 156. The point is of galvanized malleable iron. The cap is of brass, with a lug, the hole in which is tinned, so that the ground wire can be soldered into it. Fig. 63 illustrates the application of these fittings for a lightning arrester on a trolley

line. In installing, the point is screwed on the ground pipe, which is then driven into the earth to a depth of 8 ft. or 10 ft. The cap is screwed on, and the ground wire soldered into it. In driving the ground pipe, a coupling should be run on the thread on the top of the ground pipe, to prevent its mutilation. Where it is inconvenient to drive the ground pipe into the earth in one length, it can be divided into two or more lengths. The first is driven in, and then the second is joined to it with an ordinary pipe coupling. Where it is desirable to limit the possibility of tampering with the ground wire, where it joins the upper end of the ground pipe, the ground pipe can be extended, for a distance of possibly 8 ft. from the surface of the earth, up to the side of a pole or building.

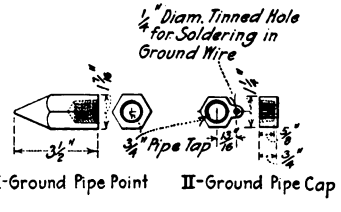


FIG. 156.—Details of point and cap castings for a ground pipe. (Westinghouse manufacture.)

A multiple- or distributive-pipe ground connection is installed, as shown in Figs. 9, 65 and 143, where it is desired to obtain an earth-connection of minimum resistance. It consists of a number of individual pipe grounds connected in multiple. Obviously the resistance of two-pipe earth-connections in multiple is less than the resistance of one connection and it follows that the greater the number of pipes connected in multiple, within reasonable limits, the less will be their combined resistance. Fig. 65 shows an example of a multiple-pipe connection where 12 pipes driven into the ground around a station are all connected in mulitple by a conductor, encircling the building under the ground surface. The connections between the various pipe units may be made by using special connectors like those of Figs. 152 or 154, or a ground wire may be soldered to the tops of the different pipes as shown in Fig. 143. The portions of the pipes adjacent to the copper ground lead should be thoroughly tinned as should the ground lead itself, to prevent electrolytic action between the dissimilar metals.

The methods of improving the conductivity of pipe or rod earth-connections are illustrated in Figs. 144, 145 and 146. In Fig. 146 is shown a method described in THE FACTORY MUTUAL FIRE INSURANCE RULES under *Rule 5c.* It consists in digging a hole 4 ft. or 5 ft. deep around the ground rod, and filling it with crushed coke or charcoal about pea size. This is said to compensate in a measure for the lack of moisture that may sometimes be encountered. In Fig. 144 salt is packed around the upper end of the ground rod and water is poured on the salt. The salt solution percolates down through the soil around the rod, increasing the conductivity of the adjacent soil. This has the effect of increasing the contact area of the ground rod with the soil and decreases the resistance of the earth-connection. The salt should never be packed high enough that it will attack the point of connection between the ground lead and the pipe. Tests have shown that the resistances of pipe earth-connections can be very materially lowered by the application of a salt-and-water solution as above described.

An iron-pipe ground with a rock-salt filling is illustrated in Fig. 145. Grounds of this type are described and recommended by G. H. RETTEW, Electrical Engineer of the Potomac Power Company, in the *General Electric Review* for September, 1915. In this article it is asserted that the average resistance of 100 ground connections of different forms and of various ages was found to be approximately 200 ohms. Obviously, an earth-connection having such a high resistance cannot be very effective for secondary grounding. A connection of the type illustrated in the figure has, it is claimed, the advantage of initial low resistance and of maintaining this low resistance permanently. The average resistance of 250 grounds of this type was 15.7 ohms each. The feature is a rock-salt filling which, when dissolved, permeates the soil, increasing its electrical conductivity.

The directions for installing the salt-filled pipe ground are as follows: First a 2-in. wrought-iron pipe (outside diameter 2⅜ in.) is driven into the earth (at the point where the ground connection is to be made) for a distance of 5 ft. It is then

withdrawn. The cylindrical cavity thus formed is filled with rock salt as shown in the illustration. Now a 12-ft. length of ¾-in. galvanized-iron pipe is driven through the 5-ft. salt stratum and about 5 ft. further down into the earth. The top end of the pipe which is mutilated by its being driven into the earth is then cut off and threaded. Now another length of ¾-in. pipe about 10 ft. long is connected with a coupling, to the length in the ground. A trench is then dug from the ground pipe to the pole and the extending length of pipe is formed into the trench and bent up the pole. It can be held thereto with pipe straps. The top end of the ground pipe will then be approximately 10 ft. above the earth's surface as shown.

Obviously, the pipe driven into the earth must be located at least a couple of feet away from the pole to permit the turning of the pipe-cutting and threading tools above referred to. To effect a connection with the ground wire, a brass coupling of essentially the form shown in the picture is turned on the threaded end of the ground pipe. The copper ground wire coming down from the top of the pole is then soldered into the tinned hole provided for its reception in the coupling. It is claimed that an open coupling similar to that shown is preferable to a cap which encloses the end of the ground pipe, because the open coupling permits some rain and moisture to enter the pipe so that it can flow down therein and increase the conductivity of the adjacent soil. It is stated that when the first length of pipe is driven into the ground a considerable quantity of salt remains within it. This salt is slowly dissolved by the water which comes down inside of the pipe.

Ground rods, Fig. 157, are sometimes used instead of ground pipes. They find their principal application for grounds for telephone and other small lightning arresters. These ground rods are usually about 6 ft. long and ½ in. in diameter and therefore are not sufficiently heavy for ordinary electric light or power work. The conditions affecting their installation are essentially the same as those described in connection with the ground pipes as outlined in the preceding paragraph. It is obvious that a ground pipe will, for a given amount of material,

be longer and stronger than a solid rod. For this reason pipes are used more frequently than solid rods.

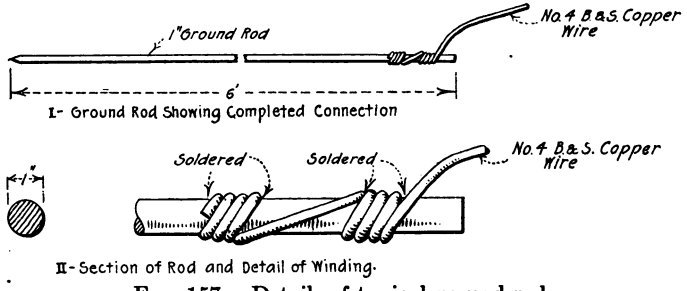


FIG. 157.—Details of typical ground rod.

RESISTANCE OF DIFFERENT TYPES OF GROUND CONNECTIONS

From Report of Committee on Transmission and Distribution of Electrical Energy of the OHIO ELECTRIC LIGHT ASSOCIATION, *Electrical World*, Nov. 13, 1915, page 1088.

No.	Description	Ohms
1	10 lb. scrap copper set 6 ft. deep, surrounded by 10 lb. coke	14.2
2	Copper plate, 5 ft. by 3½ ft., set 4 ft. deep, surrounded by 2 ft. crushed coke	5.6
3	One 9-ft. length 1¼-in. black iron pipe driven 6 ft. in solid earth	25.1
4	One 9-ft. length 1¼-in. galvanized-iron pipe driven 6 ft. in solid earth	24.5
5	One 12-ft. length 1¼-in. black iron pipe driven 9 ft. in solid earth	14.8
6	One 12-ft. length 1¼-in. galvanized-iron pipe driven 9 ft. in solid earth	18.4
7	Two 9-ft. lengths ¾-in. galvanized-iron pipe set 6 ft. deep and coke tamped around pipes	15.2
8	One 9-ft. length 1¼-in. galvanized-iron pipe set 6 ft. deep and coke tamped around pipe	26.7
9	Perforated metal cone 18 in. long, filled with charcoal, buried 6 ft. in 2 ft. of coke	14.4
10	Patented type of driven ground pipe	19.5
11	Patented type of set ground connection	11.7
12	Connection to city water system at faucet placed about 100 ft. from test grounds	00.44

Questions. Class B

43. Why should constant-potential lines having a voltage of over 5,000 be carried no closer to adjacent lines than the distance equal to the height of the taller pole line?

44. What are the smallest sizes of wires permissible in trolley line construction?

45. What provisions should be made with constant-potential pole lines (over 5,000 volts) to reduce the possibility of breakdowns in the lines?

46. What kind of insulation is acceptable for outdoor line wires?

47. In direct-current, three-wire systems, of what size must the gound wire be at central stations? What size in alternating-current systems?

48. Under what conditions may transformers be attached to the sides of buildings?

49. What is a ground plate? How is it installed?

50. What is a drip loop? Where should it be used, and why?

51. What are the requirements affecting the grounding of the neutral wire of a direct-current three-wire system at (*a*) central stations, (*b*) underground systems, (*c*) overhead systems?

52. Name and describe several approved methods of attaching ground wires to piping systems.

53. What is an end-insulator guard and under what conditions is it used?

54. State several precautions which must be taken when supporting line wires.

55. When a ground wire or ground connection is inside of or attached to a building, what are the specifications governing the selection and size of such a ground wire?

56. Why must the piping system to which ground wires are connected present a continuous and complete metallic circuit?

57. How must conduit runs carrying service wires be installed with respect to conduit, metal molding or armored cable runs within a building?

58. How must ground wires be supported when attached to poles or sides of buildings?

59. State briefly the important requirements governing the grounding of outside wires.

60. What general rules must be observed in carrying high voltage constant-potential pole lines near buildings?

61. What special requirements affect the installation of trolley wires, with respect to facilitating the work of firemen in the case of fire?

62. What kind of insulation from ground is required for trolley wires?

63. Describe the type of insulator required for the support of outside wires exposed to the weather.

64. What precautions against cross connections resulting from moisture must be followed when installing outside line wires?

65. What is the maximum spacing distance between supports for outside line wires carried on the exterior of building walls?

66. State the requirements governing the making of splices and joints in outside line wires.

67. How may low-potential service wires be brought into buildings?

68. State the requirements which affect the grounding of metallic sheaths of cables used in outside work.

69. How are low-potential overhead-service wires grounded?

70. How is the neutral wire of a direct-current, three-wire system grounded at the central station?

71. What are the grounding requirements affecting the neutral of underground, direct-current, three-wire systems? Overhead systems?

72. What type of ground connection is permissible for individual transformers?

CLASS C

(Rules 16 to 19 inclusive)

INSIDE WORK

(Including All Work for Light, Power and Heat Protected by Service Cut-out and Switch. For Signaling Systems see Class E)

ALL SYSTEMS AND VOLTAGES

GENERAL RULES

16. WIRES.

(See also Nos. 17, 18, 20, 26, 27, 44, 47 and 48. *For construction rules see Nos.* 49 *to* 57)

16*a*. ¶*I*. WIRES. Must not be of smaller size than No. 14 B. & S. gage, except as allowed for fixture work and pendant cord.

Conductors smaller than No. 14 B. & S. gage should not be used in electric light or power wiring, except for wiring fixtures and for flexible cords, because wires smaller than this do not have sufficient mechanical strength to insure them against breakage. Stresses are frequently imposed on the conductors of a wiring system after the system has been installed and concealed by the walls and partitions of a building. Such stresses may be due to the warping or shrinking of timbers, to the settlement of buildings or to excessive vibration. If a wire upon which voltage is impressed is broken, due to these strains, it might start a fire. Such a fire might, before discovery, gain considerable headway within a partition or wall.

Wires for fixture work (see discussion under *Rule* 30*c*, ¶*I*) may be as small as No. 18 because such conductors are always protected within the metallic tubing of fixtures or within fittings, so that if they do break, damage would not be likely to result. Furthermore, the wires within fixtures are not ordinarily drawn taut and therefore are not so liable to be subjected

to tensile stresses. See *Rule* 52 for specifications for approved fixture wire.

Flexible cords should always (*Rule* 32*g*, ¶*I*) be exposed and hang free in air and should not have extreme tensile stresses imposed on them. Furthermore, it is desirable from the standpoint of appearance that they be of small diameter. For these reasons, experience has shown that No. 18 gage flexible cord is on the whole reasonably safe and satisfactory. See *Rule* 51 for specifications for approved flexible cords.

16*b*. ¶*I*. WIRES. Conductors of size No. 8 B. & S. gage or over used in connection with solid knobs must be securely tied thereto. If wires are used for tying they must have an insulation of the same type as the conductors they confine. Split knobs or cleats must be used for the support of conductors smaller than No. 8 B. & S. gage.

Insulators for interior electric wiring are ordinarily of porcelain. Fig. 158 shows typical insulators of this material. Practically all of the porcelain fittings on the market are now

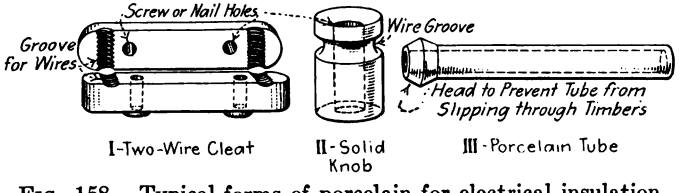


FIG. 158.—Typical forms of porcelain for electrical insulation.

made to conform with CODE specifications and therefore will provide proper insulation if used for the services for which they were designed. The specifications and dimensions for porcelain tubes and bushings are given in *Rule* 61; specifications for cleats in *Rule* 62; specifications and dimensions for knobs in *Rule* 64.

Wires for light and power wiring should never be supported directly against the surface upon which they are carried. For example, the method of attaching a conductor directly to the supporting surface with staples as shown in Fig. 159 has been shown by experience to be very unsafe and unsatisfactory. In the earlier days of electric lighting this method

was used and doubtless many fires resulted therefrom. If an attempt is made to support a wire to a surface with a staple, the staple will in practically every case cut through the insulation and may break the metal conductor. An electric arc can originate from such a condition which would ignite the insulation on the conductor.

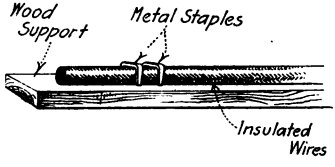


FIG. 159.—An extremely unsafe method of supporting conductors.

The method of tying a conductor on a solid knob is shown in Fig. 160. In making such a tie, the tie-wire is bent into a U-shaped form, then placed in the groove of the knob and its ends served around the conductor to be tied, as shown in the illustration. Such a tie should have at least three, and preferably four, "end turns."

Tie-wires should have the same insulation as the wires they support to the knob for the following reasons: If bare wire, or a wire with thin insulation, is used for a tie it is liable,

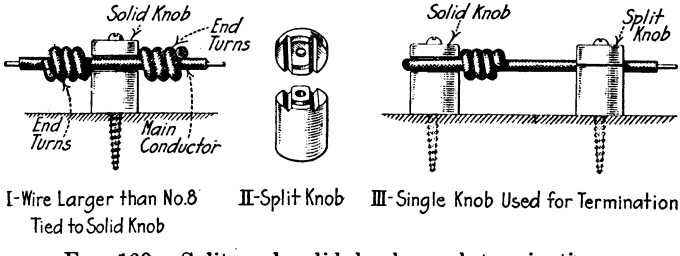


FIG. 160.—Split and solid knobs and terminations.

when being served on the main conductor, to cut into the insulation on the conductor and damage it. If a bare wire is drawn up too tightly around the main conductor it may shear the conductor asunder. Furthermore, if the tie-wire is not insulated, or is thinly insulated, it may be twisted into contact with the metal of the main conductor and thereby provide a possible leakage path. A heavily insulated tie-wire is obviously not as liable to cut into the insulation of

the wire which it confines as would be a bare or lightly insulated wire, because of the greater outside diameter of the heavily insulated conductor.

Split knobs should be used for intermediate supports for conductors smaller than No. 8, because if solid knobs were used, tie-wires would be required. Experience has shown that the tie-wire method of attachment is unsatisfactory for small conductors, because there is a possibility of a small main conductor being sheared off or strained when a tie-wire is served about it. Small diameter tie-wires would be used for supporting small-diameter conductors to knobs. Such tie-wires would be readily untwisted by the application of a small force and then might permit the main wire to drop down on

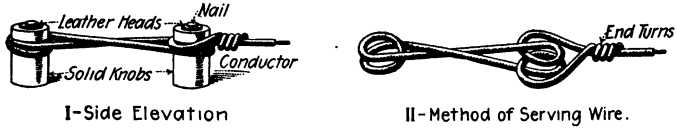


FIG. 161.—Two solid knobs used for dead end for sustaining heavy-strain run.

the supporting surface or pull away from the knob. Solid knobs, Fig. 158, *II*, were formerly used for all work but now, split knobs are, in general, considered preferable for supporting wires smaller than No. 8.

The method of terminating a No. 8 or larger conductor on a solid knob at the end of a run is shown in Fig. 160, *III*. Where the strain assumed by the conductor is severe, it is frequently desirable to use two knobs at the termination of a run as shown in Fig. 161.

Strain insulators may be used at the terminations of heavy-conductor runs as shown in Figs. 162 and 163. Where the conductors are larger than say, possibly No. 6 and exposed, strain insulators provide the best method of termination. In the installation of Fig. 162 a porcelain insulator held to an eye bolt set in the joist is used. This method is ordinarily applied only for medium-sized conductors, possibly those between No. 6 and No. 0, B. & S. gage. Where larger conductors are to be terminated, a composition strain insulator of

the type used in overhead line construction can be utilized in combination with a cable clamp, as shown in Fig. 163, to provide a very substantial and sightly installation.

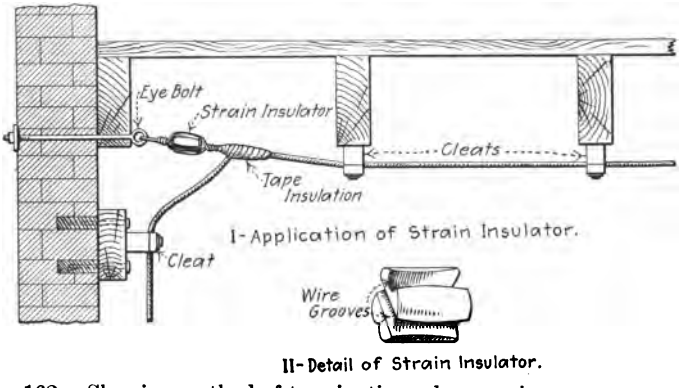


FIG. 162.—Showing method of terminating a heavy-wire run on a porcelain strain insulator.

Split knobs or cleats are used for supporting conductors smaller than No. 8, B. & S. gage, because, as suggested above, the method of supporting them on solid knobs, which necessi-

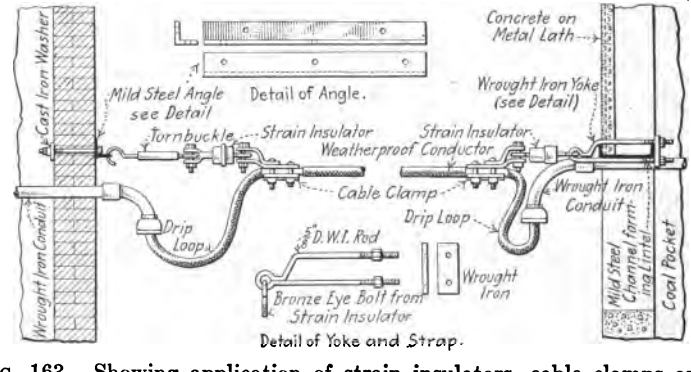


FIG. 163.—Showing application of strain insulators, cable clamps and turnbuckles for heavy-run terminations.

tates the use of a tie-wire, has not been satisfactory. With a split knob, Fig. 160, *II* and *III*, the wire is clamped between the base and the cap of the knob and will be held securely,

provided the wire is not too large. Several satisfactory types of split knobs are obtainable. That shown in Fig. 160 is typical.

Tie-wires and knobs do not provide a satisfactory support for large conductors in spite of the fact that the CODE permits their application for this service. The weight of a large conductor, or the longitudinal strains that it imposes often loosens the tie-wire and permits the conductor to sag down on the knob or to pull away from it. Fig. 164 indicates the most satisfactory method of insulating such heavy conductors from their supporting surface. The wire may be held between two solid knobs, as indicated at the left of the illustration, or in a single-wire cleat of suitable proportions, as shown at the right. Fig. 162 also shows a heavy conductor supported in cleats.

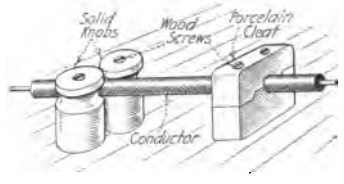


FIG. 164.—Method of supporting very heavy conductors.

16*b*. ¶*II*. WIRES. Knobs or cleats which are arranged to grip the wire, must be fastened by either screws or nails. If nails are used, they must be long enough to penetrate the woodwork not less than one-half the length of the knob and fully the thickness of the cleat, and must be provided with washers which will prevent under reasonable usage, injury to the knobs or cleats.

Either screws or nails may be used for fastening knobs or cleats. At one time it was considered best practice to fasten all knobs and cleats with screws, but it was then found that a great many knobs and cleats were broken, due to the screws being set up too tightly. Frequently the breakages would occur a considerable time after the screws had been driven, due possibly to expansion or contraction caused by heat, or to the swelling or warping of the wood. Such breakages have occurred within walls and partitions after the completion of the plastering. The wire originally confined by the knob was then permitted to sag uninsulated against the wood and plaster and thereby constituted a fire risk. If nails are used for supporting knobs or cleats, with a leather washer between the

nail head and the porcelain as shown in Fig. 165, the breakage of porcelain is, so experience has shown, much decreased.

Furthermore, the tendency of the average wireman is, if screws are used, to drive them in with a hammer so that they then exert but little if any more holding power than do nails. There are, however, certain conditions which necessitate the use of screws for supporting knobs or cleats. For example, if a knob or cleat is to be fastened to a relatively thin piece of wood, a nail will not hold it securely nor will a nail under these conditions have a hold in the wood equal to half the length

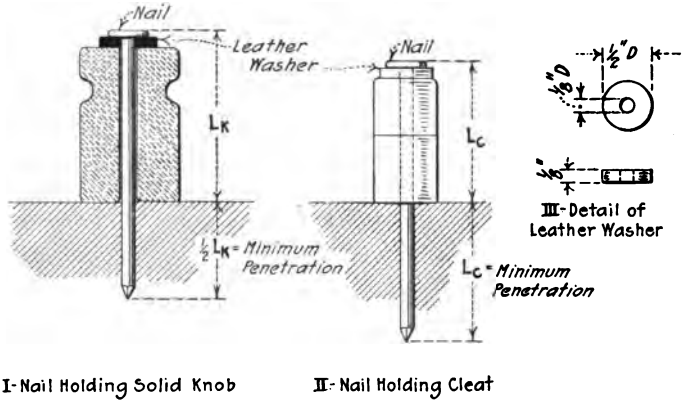


FIG. 165.—Showing application of nails for securing cleats and knobs.

of the knob, or equal to the thickness of the cleat, as it should have to satisfy the requirements of the above *Rule* 16*b*, ¶*II*. Fig. 165, *I*, indicates the minimum permissible penetration for a nail holding a solid knob. In *II* the minimum permissible penetration for a nail supporting a cleat is shown.

Leather washers are used to prevent injury to knobs or cleats. The washers lie, after the nails are driven, between the nail head and the porcelain. At Fig. 165, *III*, are indicated the approximate dimensions of leather washers, or as they are sometimes called, leatherheads, ordinarily used in interior-wiring construction for knob-and-tube work. The outside diameter and the diameter of the hole are always approximately those shown in the illustration, but the thick-

nesses of the washers vary over a wide range because they are punched from scrap leather. Where the leather is thin, two or more washers should be packed together on one nail to form a suitable cushion. The thickness of such a leather cushion under a nail head should never be less than ⅛ in.

16c. ¶*I*. WIRES. Must be so spliced or joined as to be both mechanically and electrically secure without solder. The joints must then be soldered unless made with some form of *approved* splicing device, and covered with an insulation equal to that on the conductors.

The splicing of wires for inside work is effected in accordance with practically the same methods as are used for splicing outside conductors and as described under *Rule* 12*e*. See the author's AMERICAN ELECTRICIANS' HANDBOOK for further information relating to the splicing of conductors.

16 *c*. ¶*II*. WIRES. Stranded wires (except in flexible cords) must be soldered before being fastened under clamps or binding screws, and whether stranded or solid, when they have a conductivity greater than that of No. 8 B. & S. gage they must be soldered into lugs for all terminal connections, except where an *approved* solderless terminal connector is used.

The ends of stranded wire should be soldered into a solid bundle before being fastened under binding screws or clamps. When the unsoldered end of a stranded conductor is placed in a terminal clamp and the screw is turned down, the small component conductors spread out and render difficult the provision of an attachment that is mechanically secure and which has good electrical conductivity. On the other hand, if the strands are all soldered into a compact bundle, the clamp will grip it fairly and firmly. Practically the same difficulty occurs if an endeavor is made to fasten the unsoldered end of stranded wire under a binding screw. The binding screw, when it is set down, will force the unsoldered ends apart and may "bite" into some of the small component conductors. Furthermore, it frequently occurs that where all of the strands of a conductor are not soldered together prior to being placed under a clamp or set screw that one or two of the strands may be forced to carry all the current and may thereby become dangerously overheated.

Wires larger than No. 8 should always be soldered into lugs at terminal connections, because this is the only method which provides a substantial connection. It is difficult to bend wires larger than No. 8 around binding screws and in bending them the binding screws may be strained. In setting a binding screw down on a heavy conductor which is bent around it, its threads, or the threads of the metal into which it turns, are often sheared. These difficulties are not likely to occur when terminal connections are made with lugs soldered on the ends of the wires. In soldering a lug on a wire, the insulation of the wire end should be trimmed back for a distance not greater than the depth of the hole in the lug.

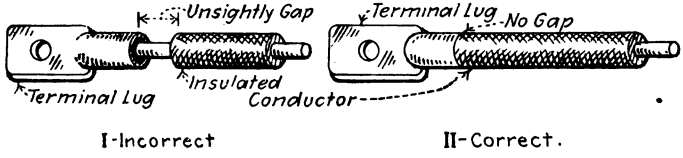


FIG. 166.—Correct and incorrect methods of soldering lugs on conductors.

It will then, when soldered into the lug, appear as shown in Fig. 166, *II*. If the insulation is trimmed back too far there will be an unsightly gap exposing a section of the conductor between the insulation on the conductor and the end of the terminal lug, as shown at *I*.

16*d*. ¶*I*. WIRES. Must be separated from contact with walls, floors, timbers or partitions through which they may pass by non-combustible, non-absorptive, insulating tubes, such as glass or porcelain, except at outlets where *approved* flexible tubing is required.

Wires passing through floors, timbers or partitions, should be insulated therefrom with porcelain tubes, as shown in Figs. 167, 168, 169 and 170. Any substance other than an insulating material, such as porcelain or glass, through which a wire passes must be considered as a possible conductor. For example, wood, when moist or wet, becomes a fairly good conductor as do masonry and most other building materials. It is for these reasons that holes should be bushed with a non-conductor. Porcelain bushings are used because—all things

considered—this is the most adaptable insulating material. If thorough insulation is not provided there is always a possibility of current "leaking" from a conductor through damp woodwork or masonry to another conductor of opposite polarity which may or may not be grounded. Such current leakages have been known to cause fires and to "eat" the conductor in two due to electrolytic action. A conductor thus

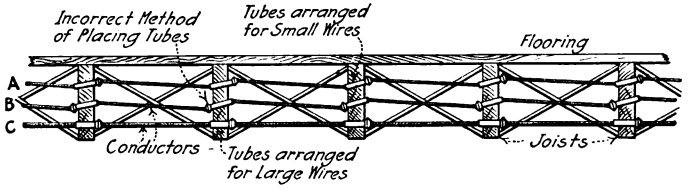


FIG. 167.—Methods of placing tubes in joists.

broken and upon which voltage is impressed may, obviously, originate a fire. Insulating tubes should always extend a distance of from ½ to ¾ in. on both sides beyond the member that they bush. Furthermore, they should not extend much farther than ¾ in. because of the liability to breakage where the extension is too great.

The methods of bushing conductor holes in joists with porcelain tubes are shown in Fig. 167. Where the conductor is of small diameter it is usually considered preferable to bore the holes for the tubes on a slant as shown on runs *A* and *B* in Fig. 167. Where this is done, the tubes should be inserted with the enlarged end at the upper outlet of the hole so that the enlargement will prevent the tube from slipping through the hole. The tubes should not be inserted as shown in run *B* with the enlarged ends at the lower openings of the holes because then their tendency is to fall out. When the tubes are inserted as in run *A* and the conductor through them is drawn taut, the bushings are held very firmly in position.

FIG. 168.—Masonry wall bushed with iron pipe, porcelain tubes providing insulation.

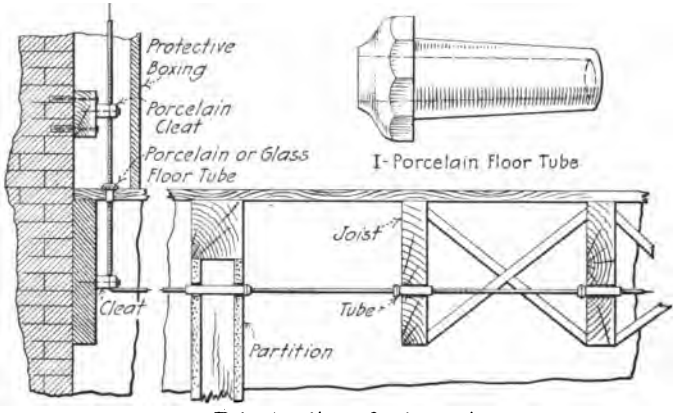


FIG. 169.—Illustrating the use of porcelain tubes and cleats for insulation.

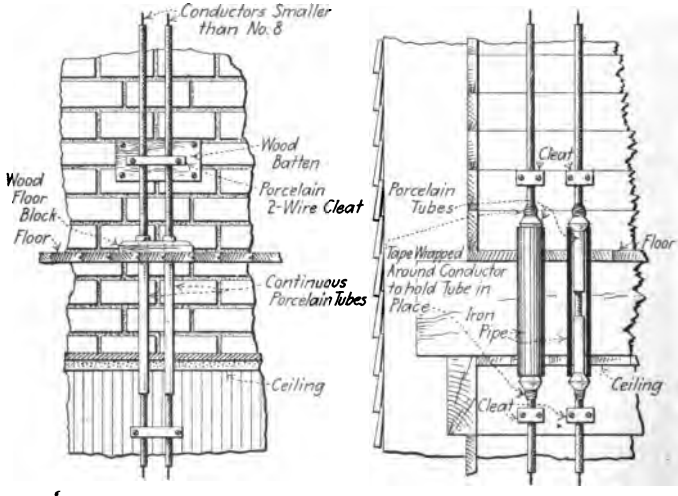


FIG. 170.—Showing methods of carrying open-work conductors through floors encased on porcelain tubes.

The usual practice with wiremen, however, when working in buildings under construction, is to bore the holes through joists at right angles to the faces of the joists as shown in Fig. 167, *C*, because where this is done it is somewhat easier to insert the tubes and to thread the wires through them. Holes can also, where modern joist-boring machines are used, be bored more readily at right angles to the faces of the joists than on a slant. In boring holes in joists in finished buildings which are being wired, the holes are ordinarily bored on a slant because then the wireman works from the floor above the space between the joists and it is then easier to bore holes on a slant than at right angles to the face of the joist. Where the conductor is of large diameter the tube holes and tubes should be in line with each other and perpendicular to the joist faces, because if they are not, it is difficult to thread the conductors through them. Furthermore, after the wires are threaded through, if the tubes are not in line and a strain is imposed on the conductor, some tubes are liable to be broken. Fig. 169 shows how a porcelain floor tube, especially designed for the purpose, is applied. Where conductors pass through a floor as shown, boxing should be installed around them as described under *Rule* 26*e*, ¶*II*.

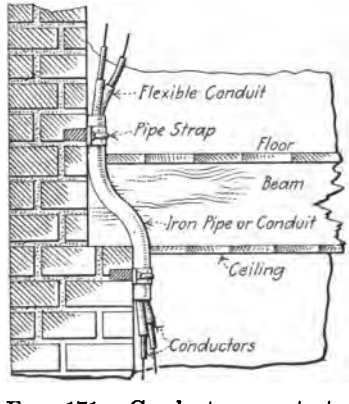


FIG. 171.—Conductors protected by iron pipe passing through floor.

16*d*. ¶*I*. WIRES. Bushings must be long enough to bush the entire length of the hole in one continuous piece, or else the hole must first be bushed by a continuous waterproof tube. This tube may be a conductor, such as iron pipe, but in that case an insulating bushing must be pushed into each end of it, extending far enough to keep the wire absolutely out of contact with the pipe.

Bushings must be continuous through the entire length of a hole. This requirement is satisfied where one continuous

porcelain tube extends through a hole, as through the partition in Fig. 169, or through the joist of Fig. 167. Where it is not feasible to bush the hole with one continuous length of porcelain the hole may be first bushed with a "waterproof" (a piece of iron pipe) tube and this tube re-bushed with porcelain as shown in Fig. 168 and 170, *II*. Where it is impossible to use a straight length of pipe, re-bushed with porcelain, it is permissible to bend the pipe as shown in Fig. 171, *III* and insulate the conductors which pass through it with flexible conduit, *provided* the location is dry. Where a wall is so thick that two tubes of the lengths available are not sufficient to bush the pipe through it as shown in Fig. 168 then a third piece of flexible tubing can be inserted in the space between the two tubes, provided the location is dry.

16*e*. ¶*I*. WIRES. Where not enclosed in *approved* conduit, moulding or armored cable and where liable to come in contact with gas, water, or other metallic piping or other conducting material, must be separated therefrom by some continuous and firmly fixed non-conductor creating a permanent separation. Must not come nearer than two (2) inches to any other electric lighting, power or signaling wire, not enclosed as above, without being permanently separated therefrom by some continuous and firmly fixed non-conductor. The non-conductor used as a separator must be in addition to the regular insulation on the wires. Where tubes are used, they must be securely fastened at the ends to prevent them from moving along the wire.

The Protection of Conductors against Accidental Contact with Pipes, Metallic Conducting Material, or Other Conductors.—The first sentence of *Rule* 16*e*, ¶*I*, specifies how conductors *in dry places lying near pipes* or other conducting material should be protected against contact therewith. The remainder of 16*e* specifies how conductors *in dry places lying near other conductors* should be protected. *Rule* 16*f* indicates the protection that must be afforded *conductors in wet places* against contact both with other conductors and with metallic objects. The three conditions just noted are discussed in following paragraphs.

Methods of protecting conductors in dry places against contact with piping or other conducting material are illustrated in Figs. 172, *II*, 173, *II*, *III* and *VI*. Either flexible tubing or

a porcelain tube may be used on conductors or wires for protection in such locations. Porcelain tubes are preferable, but flexible tubing is frequently used, particularly where the wire-

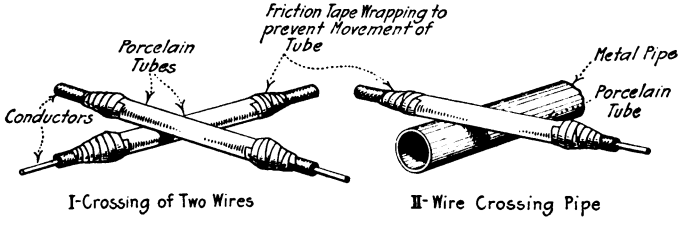


FIG. 172.—Showing method of securing tubes on the conductors they protect.

man fails to slip a porcelain tube on the conductor before it is pulled into position. In this event he can split a length of flexible tubing longitudinally, snap it around the conductor

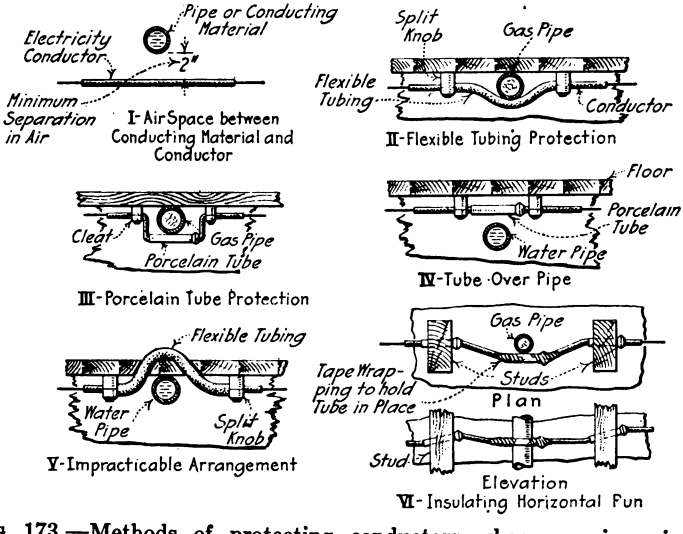


FIG. 173.—Methods of protecting conductors where crossing pipes.

and tape it in place. Split porcelain tubes can also be used for this service, but usually they are not available. Either flexible tubing or porcelain tubes on a conductor must be

prevented from slipping, either by taping their ends to the conductor as shown in Fig. 172, *II*, or by placing knobs (or cleats) at either end of the tube as shown in Fig. 173, *III* and *IV*. A water-pipe crossing is ordinarily considered a "wet place" regardless of where it is located in a building, because a water pipe is always liable to "sweat" and thereby saturate with moisture things that touch it. Gas and soil-pipe crossings are ordinarily considered as dry places unless they occur in a basement or bathroom or in some location which obviously *is* a wet place.

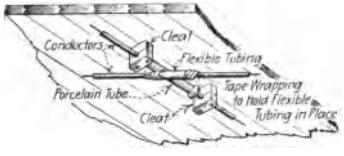


FIG. 174.—Flexible tubing used for conductor insulation at a crossing.

Methods of protecting conductors in dry places from contact with other adjacent conductors which they cross are shown in Figs. 172, *I*, 174, 175 and 176. Note that if a 2-in. air space can be provided between the crossing conductors, additional insulating protection is not necessary. Ordinarily where conductors of opposite polarity or of different systems cross, it is necessary to put a tube on only one of the crossing wires as shown in Fig. 175. However, tubes are occasionally

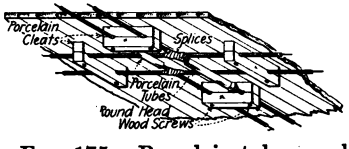


FIG. 175.—Porcelain tubes used for insulating conductors at a crossing.

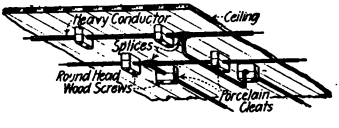


FIG. 176.—A crossing of heavy conductors.

applied as shown in Fig. 172, *I*. Flexible tubing is sometimes used for this service instead of porcelain tubes under conditions specified in the preceding paragraph and as shown in Fig. 174. However, porcelain undoubtedly provides the most effective insulation. Where large conductors, say those exceeding No. 6, B. & S. gage, cross one another in exposed work, a crossing made as shown in Fig. 176, by forming a bend in one of the conductors at the crossing point, is ordinarily acceptable,

particularly if all of the conductors are substantially supported, as shown, by cleats. In any case, where flexible tubing or tubes are utilized for protecting conductors at crossings they must be securely held in proper position (Figs. 172, *I*, and 175), either by cleats or knobs or by a tape wrapping.

16*e*. ¶*II*. WIRES. Deviations from this rule may, when necessary, be allowed by special permission.

16*f*. ¶*I*. WIRES. Must be so placed in wet places that an air space will be left between conductors and pipes in crossing, and the former must be run in such a way that they cannot come in contact with the pipe accidentally. Wires should be run over, rather than under, pipes upon which moisture is likely to gather or which, by leaking, might cause trouble on a circuit.

Where conductors cross metallic objects or other conductors in wet places a 2-in. air space should always be provided between the conductor and the object which it crosses, as shown in Fig. 173, *I* and *V*, and in Figs. 177 and 178. Frequently, where it is difficult or impossible to provide this 2-in. air space,

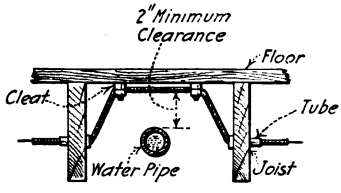


FIG. 177.—Wiring around a pipe in a damp place.

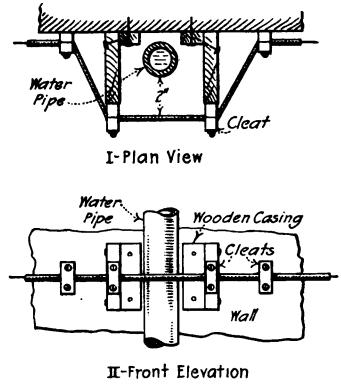


FIG. 178.—Method of carrying conductor around a vertical pipe.

inspectors will accept crossings made as shown in Fig. 173, *III* and *VI*, where porcelain tubes are placed on a conductor for its protection.

Wires should be run over rather than under pipes subject to dampness (Figs. 172, *II* and 173, *IV* and *V*) so that there will be minimum likelihood of the moisture from the pipe permeating the insulation on the conductor. However, in practice it often occurs that this rule cannot be followed rigidly. In such cases inspectors will frequently approve an

installation, in accordance with the terms of *Rule* 16*e*, ¶*II*, permitting the conductor runs *under rather than over* a damp pipe, particularly if in addition to the 2-in. air space required in damp places, porcelain tubing is used on the conductor for insulation. Where a conductor is to be protected from possible contact with a vertical damp pipe, a "bridge" may be arranged around it as shown in Fig. 178.

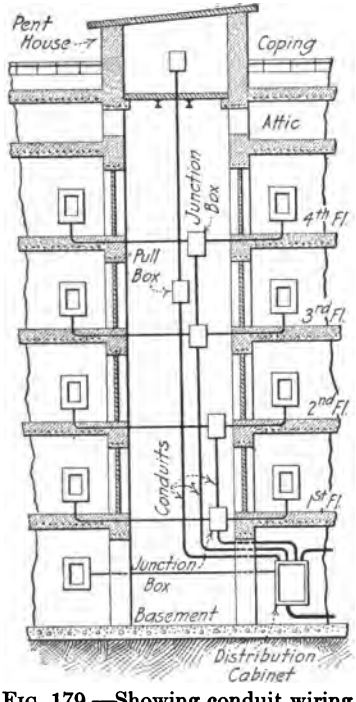


FIG. 179.—Showing conduit wiring in an elevator shaft.

16*g*. ¶*I*. WIRES. The installation of electrical conductors in moulding, or on insulators, in elevator shafts will not be approved, but conductors may be installed in such shafts if encased in *approved* metal conduits, or armored cables.

Electrical conductors in elevator shafts should not be supported on insulators or in molding because experience has shown that wires installed in accordance with these methods are frequently displaced and sometimes short-circuited. Another objection to wooden molding is that it is likely to carry fire, if it is started, from the bottom of the shaft to the top because of its combustible nature and because of the strong drafts that frequently exist in elevator shafts. Conduit should be used as shown in Fig. 179 where it is desirable—and it frequently is—to install conductor runs in elevator shafts.

16*h*. ¶*I*. WIRES. In three-wire (not three-phase) systems, the neutral must be of sufficient capacity to carry the maximum current to which it may be subjected.

Three-wire system neutrals are discussed under *Rule* 23*a*, ¶III. Three-wire systems and the principles of their opera-

tion are described in the author's AMERICAN ELECTRICIANS' HANDBOOK.

The size of the neutral wire in a three-wire system may be determined to some extent by whether or not the neutral is grounded. If the neutral is grounded, then no automatic cut-out (fuse or circuit-breaker) should be inserted in the neutral of any *service* wire, *Rule* 23*a*, ¶*III*. Now where there is no cut-out in a neutral wire it may, under conditions explained under *Rule*, 23*a*, ¶*III*, have to carry the same current as either of the outside wires; hence the neutral wire of a *grounded-neutral three-wire service* should be the same size as the outer wires. Furthermore, *Rule* 23*b*, ¶*II* specifies that a cut-out "must not be placed in any permanently grounded wire," except (*Rule* 23*d*, ¶*V*) in the wire of a two-wire branch circuit which connects to a grounded neutral and which serves lamps or other translating devices.

In substance this means that the neutral wires of feeders, subfeeders and mains in grounded neutral systems must be the same size as the outer wires, for the same reasons given above. Where the neutral is ungrounded, it may be smaller than the outer wires, provided it is protected by suitable fuses which will limit (in accordance with the values of *Rule* 18) "the maximum current to which it may be subjected" to a safe value; see text under *Rule* 23*a*, ¶III, for further information relating to this matter.

17. UNDERGROUND CONDUCTORS.

17*a*. ¶*I*. UNDERGROUND CONDUCTORS. Must be protected against moisture and mechanical injury where brought into a building, and all combustible material must be kept from the immediate vicinity.

Underground entrances to buildings should be installed very carefully because frequently no fuses are provided in the entrance conductors where they connect to the mains in the street. Consequently a short-circuit between two of the entrance conductors within the building or an accidental earth-connection between one of the conductors and ground (within the building) could create a dangerous persistent arc which might originate a fire, particularly if combustible material were in its vicinity.

17b. ¶*I*. UNDERGROUND CONDUCTORS. **Must not be so arranged as to shunt the current through a building around any catchbox.**

A "catch-box" is a junction box of an underground system at which the underground mains or conductors are fused as shown in Fig. 180. Fuses were, it is said, in the pioneer days of the industry called "safety catches." Hence, a catch-box is a sort of fuse box. Consider the conditions of Fig. 180. This illustration shows a distribution panel, *A*, in a building

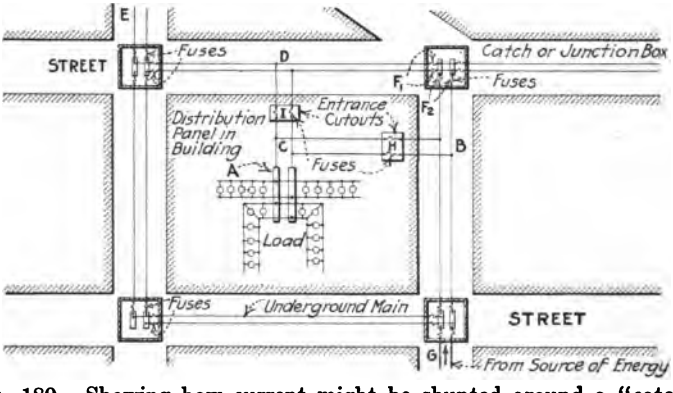


FIG. 180.—Showing how current might be shunted around a "catch" or junction box.

(in the block in the center of the picture) which is served from underground mains. This distribution panel is fed by two services, one from *D* and one from *B*. They both connect to the bus-bars of the panel at *C*. If it happened that the fuses in the junction box at F_1 or F_2 were blown, current from the source of energy *G* would feed toward *E* through the building via the route *BCD*. Now, if it so happened that for any reason the entrance cut-out at *H* and *I* failed to operate, the conductors *BCD* might carry a current far in excess of that they were designed to serve, and a fire might, under these conditions, be started. Another dangerous feature of the arrangement shown in Fig. 180 is that a person not familiar with the fact that the building shown had two entrances, might open one entrance switch, that at *I*, for instance, thinking that he had discontinued service from the building whereas voltage might still be impressed on the bus-bars via the entrance *B*.

17c. ¶*I.* UNDERGROUND CONDUCTORS. Where underground service enters building through tubes, the tubes shall be tightly closed at outlets with asphaltum or other non-conductor, to prevent gases from entering the building through such channels.

Underground entrance tubes to buildings should be closed at their ends in the buildings with asphaltum or cement, so that the gases that frequently exist in subways in underground systems cannot enter the buildings and cause explosions. Underground subways for electrical conductors are often "gassy," that is, gas leaks into them from gas mains and it may, and frequently does, mix with just the proper proportion of air to form a very explosive mixture. Manhole heads are frequently blown off in cities due to this condition, the gas becoming ignited by an accidental electric arc between the underground conductors, or by some other means.

17d. ¶*I.* UNDERGROUND CONDUCTORS. No underground service from a subway to a building, and no service from a private generating plant shall supply more than one building, except by special permission, unless the conductors are properly protected by fuses and are carried outside all the buildings but the one served. Conductors in conduit or duct under two inches of concrete under a building, or buried back of two inches of concrete or brick within a wall are considered as lying outside of the building. These requirements do not apply to factory yards and factory buildings under single occupancy or management.

18. TABLE OF ALLOWABLE CARRYING CAPACITIES OF WIRES.

(*For construction rules see Nos.* 49 *to* 57)

18. ¶*I.* TABLE OF ALLOWABLE CARRYING CAPACITIES OF WIRES. The following table, showing the allowable carrying capacity of copper wires and cables of ninety-eight per cent. conductivity, according to the standard adopted by the American Institute of Electrical Engineers, must be followed in placing interior conductors.

The allowable or safe carrying capacities of conductors are determined by the currents which these conductors will carry continuously, that is, for an indefinite period, without becoming so hot that they will injure their insulations or materials adjacent to them. Whenever a current of electricity flows through a conductor, heat is developed in the conductor. If the square of the current in amperes in the conductor be multiplied by the resistance in ohms of the conductor, the rate of heat development in watts will be the result. Note that

the heat developed varies directly as the *square* of the current, that is, if the current in any conductor be doubled the heat developed in that conductor will be increased four-fold.

The safe-current-carrying capacities as given in tables, for example, in following *Rule* 18, must not be taken as values which *cannot* be exceeded. Such values should not, however, be exceeded; hence they are safe values rather than ultimate values. For example, the safe-current-carrying capacity of No. 14 wire (rubber insulation) is 15 amp. Now, if a current of 20 amp., for example, be forced through No. 14 wire, nothing will happen except that the No. 14 wire will become warmer than it would with 15 amp. flowing through it. The chances are that if a current much greater than 15 amp. were forced through it continuously the heat developed would injure the insulation on the wire. Beginners frequently assume that the safe-current-capacity values of *Rule* 18 indicate the currents in amperes which will fuse or melt the conductors of the different sizes, to which the values apply. This impression is, of course, erroneous inasmuch as it requires currents many times as great—possibly 10 or 12 times—as those shown in *Rule* 18 to melt in two or fuse copper conductors of the sizes there given. For example, it requires a current of about 180 amp. to fuse or melt a No. 14 copper conductor, whereas the safe carrying capacity for this wire is, for rubber insulation, 15 amp. A table is given in the author's AMERICAN ELECTRICIANS' HANDBOOK showing the currents required to fuse wires of various metals and of different diameters.

18. ¶*II.* TABLE OF ALLOWABLE CARRYING CAPACITIES OF WIRES. For insulated aluminum wire the safe carrying capacity is eighty-four per cent. of that given in the following tables for copper wire with the same kind of insulation.

Safe-current-carrying capacities of aluminum wires are smaller than those for copper wires because an aluminum wire of a certain size has a greater resistance than a copper wire of the same size; hence the heat developed in an aluminum wire by the passage of a current is greater than that produced in a copper wire of the same size by the passage of the same current.

EXAMPLE.—Since, as above stated (*Rule* 18, ¶*II*), aluminum wire may be assumed to safely carry currents 84 per cent.

as great as those allowable for copper wire, a No. 3, B. & S. gage weatherproof-insulation *aluminum* wire has a carrying capacity of 0.84 × 100 or 84 amp. Note that a No. 3 weatherproof-insulation *copper* wire has an allowable safe carrying capacity of 100 amp.

18. ALLOWABLE CARRYING CAPACITIES OF WIRES—(*Continued*)

B. & S. Gage Number	Diameter of Solid Wire in Mils	Area in Circular Mils	Table A. Rubber Insulation Amperes	Table B. Other Insulation Amperes
18	40.3	1,624	3	5
16	50.8	2,583	6	10
14	64.1	4,107	15	20
12	80.8	6,530	20	25
10	101.9	10,380	25	30
8	128.5	16,510	35	50
6	162.0	26,250	50	70
5	181.9	33,100	55	80
4	204.3	41,740	70	90
3	229.4	52,630	80	100
2	257.6	66,370	90	125
1	289.3	83,690	100	150
0	325.0	105,500	125	200
00	364.8	133,100	150	225
000	409.6	167,800	175	275
		200,000	200	300
0000	460.0	211,600	225	325
		300,000	275	400
		400,000	325	500
		500,000	400	600
		600,000	450	680
		700,000	500	760
		800,000	550	840
		900,000	600	920
		1,000,000	650	1,000
		1,100,000	690	1,080
		1,200,000	730	1,150
		1,300,000	770	1,220
		1,400,000	810	1,290
		1,500,000	850	1,360
		1,600,000	890	1,430
		1,700,000	930	1,490
		1,800,000	970	1,550
		1,900,000	1,010	1,610
		2,000,000	1,050	1,670

1 mil = 0.001 inch.

The basis of the determination of the allowable carrying capacities of rubber-insulated wires is outlined in the FACTORY MUTUAL BOOK OF RULES. It was demonstrated that if maximum life was to be obtained from rubber, its temperature should at no time be permitted to exceed 150°F. The carrying capacities listed in *Rule* 18 were originally based on experiments in 1889 by A. E. KENNELLY. The allowable current values listed in *Table A* (rubber insulation) are about 60 per cent. of those which were found to produce a final temperature of 150°F. in wires of the sizes tabulated. Note that if room temperature of 75° be assumed, the rise in temperature for the final temperature of 150° is 75°. To provide a working margin, only 60 per cent. of the current that the experiment showed would produce this 150° final temperature was taken as the safe value. As the situation really stands, then, if the currents given in *Table A* flow in conductors of the sizes indicated the temperatures of the conductors will rise about 30°F. above the surrounding air.

The basis of the determination of the allowable carrying capacities of conductors with insulations other than rubber is essentially similar to that used for the rubber-insulated conductors. Insulations other than rubber will probably withstand, without damage, somewhat higher temperatures than will rubber and furthermore, "*other insulated*" conductors should never be concealed but should always be supported in the open on glass, porcelain, or other non-combustible insulating materials. Rubber-insulated conductors must often, for example in conduit or in metal molding, depend wholly on their rubber coatings for their insulation. For these reasons the safe-carrying-capacity values of *Table B* (insulations other than rubber) were taken as about 90 per cent. of the currents which were found by experiment to heat the wires to an ultimate temperature of 150°F. with a room temperature of 75°F. Hence on the basis outlined above the working margin for the conductors with insulation other than rubber is 10 per cent. of the ultimate safe value as against 40 per cent. for the rubber-insulated wires.

The current that will cause the insulation on a conductor to smoke is stated in the FACTORY MUTUAL RULES to be (approximately), for all ordinary insulations, three times the safe value given for the conductor sizes specified in *Table A* of *Rule* 18.

The allowable capacity for wires for temporary exposed work is frequently taken in practice as equal to twice the allowable capacities as specified in *Rule* 18.

EXAMPLE.—If a No. 3 wire were used for temporary connections for making the test of an electrical machine it will carry, without excessive heating, twice the tabulated value (100 amp.) that is, 200 amp. It should be understood that the information in this paragraph merely recites what is sometimes done without authority and which is considered safe in practice. The rules of the CODE do not permit allowable capacities tabulated under *Rule* 18 to be exceeded.

The allowable carrying capacities of outdoor wires are not specifically indicated in the CODE. The values of *Rule* 18, inasmuch as this rule falls within Class *C* of the CODE, apply specifically to inside work. It is the usual practice, however, to so select conductors for outside wiring that the carrying capacity values of *Table B*, *Rule* 18 will never be exceeded.

19. SWITCHES, CUT-OUTS, CIRCUIT-BREAKERS, ETC.

19*a*. ¶*I*. SWITCHES, CUT-OUTS, CIRCUIT-BREAKERS, ETC. On constant potential circuits, all service switches and all switches controlling circuits supplying current to motors or heating devices, and all fuses, unless otherwise provided (for exceptions as to switches see Nos. 8 *c*, 25 *a* and 43 *a*; for exceptions as to cut-outs see No. 23 *a* and *b*), must be so arranged that the fuses will protect and the opening of the switch will disconnect all of the wires, that is, in the two-wire system the two wires, and the three-wire system the three wires, must be protected by the fuses and disconnected by the operation of the switch.

It is usually desirable—theoretically at least—that switches and fuses control and protect all of the wires of the circuits which feed through them. The reason for this will be evident from a consideration of Fig. 181. Consider branch circuit *AA* which is fed from the mains through a single-pole switch *D* and fuse *E*. If an accidental ground occurred at *B* and another ground existed simultaneously at *C*, a short-circuit

would result as shown by the dotted arrows, even though the single-pole switch *D* were open. It is also obvious that even if *D* were closed the fuse *E* would not "blow" and open the branch circuit under the short-circuit conditions just outlined. Furthermore, if there were an accidental ground at *F* on another branch circuit *HK* then the incandescent lamps on this branch (which is protected with a fuse in only one wire), would be illuminated regardless of whether switch *D'* were open

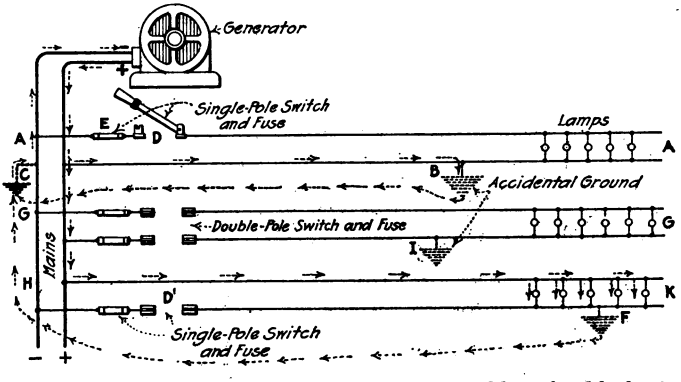


FIG. 181.—Showing why all wires of a circuit should preferably be fused and "switched."

or closed. Now, if a branch circuit is protected with a fuse in each wire and controlled by a switch blade in each wire as shown at *GG*, then the conditions outlined above which are sometimes undesirable cannot occur. In practice it is not always feasible nor desirable to fuse and switch all of the wires of all circuits. The conditions under which such fusing and switching is not desirable nor required are noted in following paragraphs.

The exceptions to the rule requiring a switch and fuse in every wire, that is, to *Rule* 19*a*, ¶*I*, are as follows:

(*I*) *Rule* 8*c* permits small motors of ¼ h.p. or less capacity on circuits of voltages not exceeding 300 to be controlled with single-pole switches where the installation is not in a damp place.

(*II*) *Rule* 23*a*, ¶*III*, specifies that a cut-out (fuse) must not be placed in any permanently grounded *service* wire.

(*III*) *Rule* 23*b*, ¶*II*, specifies that the fuse must be omitted in any permanently grounded wire, except where a two-wire branch circuit is derived from a grounded-neutral three-wire system, in which case the fuse or cut-out must be inserted.

(*IV*) *Rule* 24*c*, ¶*I*, specifies that single-pole switches may be used in inside wiring on constant-potential systems for the control of "two-wire branch or tap circuits supplying not more than 660 watts" *provided* the circuit does not feed an electric sign or is not located in a damp place.

(*V*) *Rule* 25*a* specifies that heaters of 6-amp. or 660-watts capacity or less may be grouped under the protection of a single set of fuses, provided the capacity of the fuses does not exceed 10 amp. A single-pole switch may then be used.

A fused two-pole knife switch is shown in Fig. 182. This switch is fused at the "handle" end and the fuse clips on it

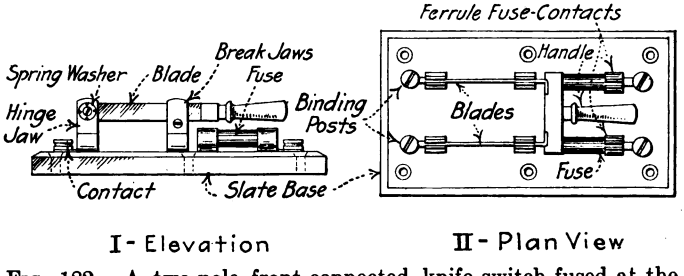


FIG. 182.—A two-pole front-connected knife switch fused at the handle end.

are of the type required to accommodate *National Code Standard* fuses of capacities of from 0–60 amp. (*Rule* 68). That is, they are of the ferrule-contact type.

A three-pole knife switch fused at the hinge end is shown in Fig. 183. Switches of this type are used for controlling three-wire or three-phase circuits. The fuse contacts are of the type required for *National Code Standard* fuses of capacities of 61–600 amp. and are known as the "knife-blade" contacts. The standard dimensions of these contacts are given in *Rule* 68. The switch is shown in the illustration mounted on porce-

lain knobs which construction is frequently adopted for wiring installations in damp places, to maintain the switch as dry as possible.

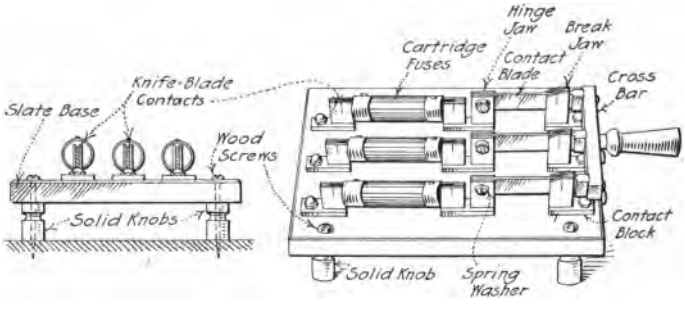


FIG. 183.—A three-pole rear-connected knife switch fused on the hinge end.

A quick-break knife switch is shown in Fig. 184. Where a knife switch of the type shown in Figs. 182 and 183 is opened under load there is always a tendency for an arc to form between the blades of the switch and the contact jaws. If the switch is opened slowly, these arcs may "eat" away the metal of the blades and contacts. This would ultimately cause a poor connection. With a quick-break switch (Fig. 184) an arc is not readily formed. The reason is, that when the main blade is opened slowly the auxiliary blade is held between the jaw contacts by friction until the main blade has been almost wholly opened. Then the spring will pull the auxiliary blade out so abruptly and rapidly that an arc will not, ordinarily, form.

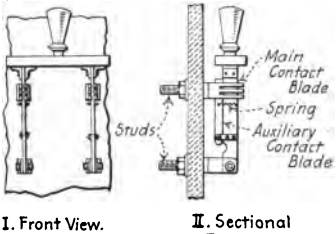


FIG. 184.—Showing the construction of a quick-break knife switch.

19a. ¶*II.* SWITCHES, CUT-OUTS, CIRCUIT-BREAKERS, ETC. When installed without other automatic overload protective devices automatic overload circuit breakers must have the poles and trip coils so arranged as to afford complete protection against overloads and short

circuits. In two- or three-phase three-wire circuits and two-phase four-wire circuits there must be a trip-coil in each of two phases, and in four-wire three-phase circuits there must be a trip-coil in each phase. If a circuit breaker is also used in place of the switch it must be so arranged that no one pole can be opened manually without disconnecting all the wires.

Circuit-breakers should be so arranged that no one pole can be opened without opening all of the poles. Fig. 185 illustrates the meaning of this requirement. For example, to open a circuit-breaker like that shown one must press up on the operating button. This disengages the trips restraining both of the arms of the breaker which permits them to open, thus disconnecting both wires of the circuit. Fig. 186 illustrates the construction of a large-capacity circuit-breaker. No solenoid is necessary for the trip coil of this breaker. The heavy current, for which it is designed, in passing through the lower copper terminal stud to the laminated copper brush creates a sufficiently strong magnetic field in the iron U-shaped yoke which is mounted over the terminal stud to trip the iron armature. When the iron armature is drawn up the breaker opens. The different methods of mechanically interconnecting the arms and electrically interconnecting the trip coils of circuit-breakers, so that they will afford complete protection for the circuits with which they are associated, are so numerous that it is not feasible to consider them here.

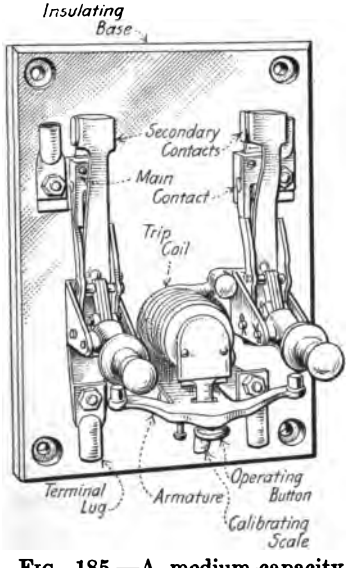


FIG. 185.—A medium-capacity, double-pole circuit-breaker (250 volts, 200 amp. General Electric Company, type C, form G).

19a. ¶*III*. SWITCHES, CUT-OUTS, CIRCUIT-BREAKERS, ETC. This, of course, does not apply to the grounded circuit of street railway systems.

A single-pole circuit-breaker provides ample protection for a grounded street railway circuit. The connections of this arrangement are shown in Fig. 187, from which it is ob-

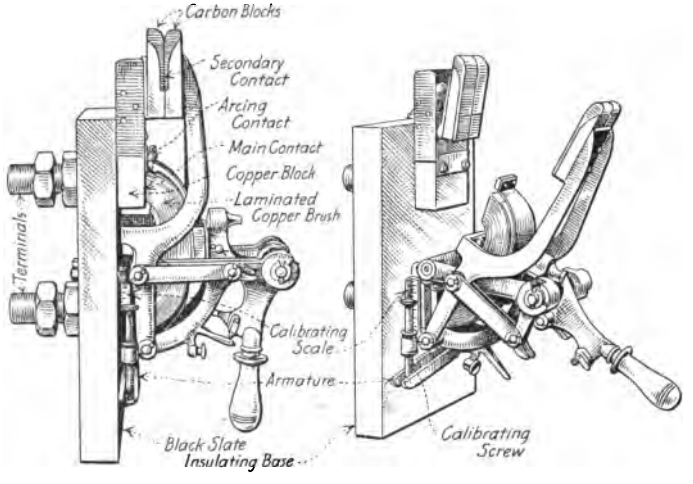


FIG. 186.—A heavy-current (2000 amp.) 650-volt, single-pole overload circuit-breaker (General Electric Company, type C, form K2).

vious, since the earth constitutes the return conductor, that nothing would be gained in so far as overload protection is con-

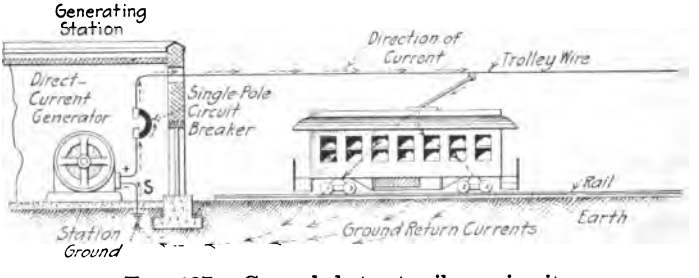


FIG. 187.—Grounded street railway circuit.

cerned if an additional breaker were inserted at *S*, that is, in the ground lead. One side—usually the negative—of every street-railway circuit is then permanently grounded.

19b. ¶*I.* SWITCHES, CUT-OUTS, CIRCUIT-BREAKERS, ETC. Must, when placed where exposed to mechanical injury or in the immediate vicinity of easily ignitible stuff or where exposed to inflammable gases or dust, or flyings of combustible material, be mounted in *approved* cut-out boxes or cabinets, except oil switches, circuit breakers and similar devices which have approved casings.

Cut-outs and switches in dirty places or where subject to mechanical injury should be protected by suitable cabinets. It is obvious that electrical fittings should be protected from mechanical injury, not only because of the defacement that may be caused thereby but also because such injury is likely to result in short-circuits or grounds which may originate fires. Furthermore, switches and fuses in dusty, dirty, or linty places should be enclosed so that the arcs that may form when fuses melt will not ignite the finely divided material in the surrounding atmosphere. Fig. 188 illustrates a type of construction of a wooden switch-and-cut-out cabinet which is suitable for use in connection with knob-and-tube or cleat work. The top and the bottom of the box are pitched so that they will not collect dirt and dust and the door is hung at an angle with the vertical, so that it will tend to always remain closed. Conductors where they enter and leave the box pass through porcelain tube bushings and the back of the box is held away from the wall, leaving a free air space by mounting it on porcelain knobs. This insures that the box will remain dry even if the wall becomes moist from rain beating against its outside surface.

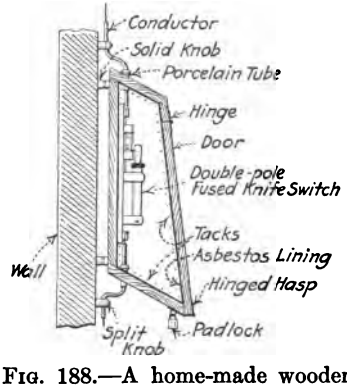


FIG. 188.—A home-made wooden cabinet.

19b. ¶*II.* SWITCHES, CUT-OUTS, CIRCUIT-BREAKERS, ETC. Cabinets and cut-out boxes must be of metal when used with metal conduit, armored cable or metal moulding systems.

Metal cabinets and cut-out boxes should be used with flexible or solid conduit and metal molding systems to insure

the electrical interconnection of the conduit and the metal-molding systems. All components of such systems should be interconnected and thoroughly grounded as specified in *Rules* 28*f* and 29*d*. Fig. 189 shows a typical, metallic switch-and-cut-out cabinet which satisfies these requirements. Metallic cabinets should be used even for knob-and-tube or open-work installations where the liability to mechanical injury is considerable. That is, steel cabinets should be used where they are located in exposed places in industrial plants and mills.

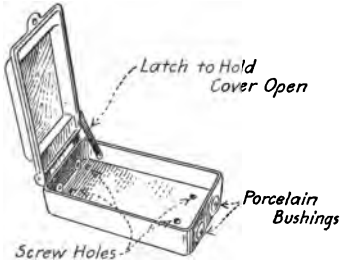


FIG. 189.—A metallic box for encasing switches or cut-outs.

Oil switches usually have dustproof cases, as shown in Fig. 190. The illustration, though it shows a small-capacity oil switch, indicates construction that is fairly typical of all oil switches and oil circuit-breakers. The welded steel tank contains the oil and is designed to hang from the top casting. It is held thereto by

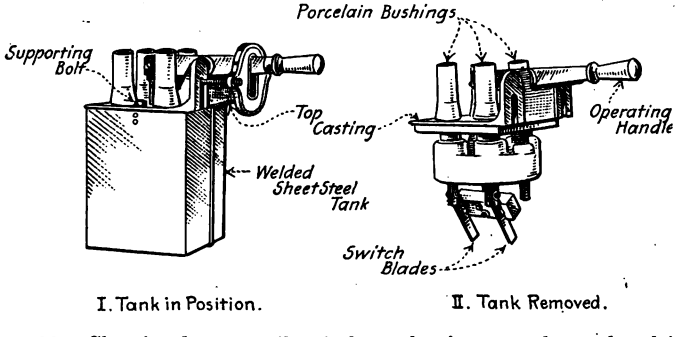


FIG. 190.—Showing how an oil-switch mechanism may be enclosed in a dust-proof casing.

supporting bolts with which the tank can be drawn tightly up against the leather gasket glued to the lower face of the top casting. Dust and dirt are thus effectively excluded.

19*c*. ¶*I*. SWITCHES, CUT-OUTS, CIRCUIT-BREAKERS, ETC. Must, when located where exposed to moisture as in basements and similar places, be mounted in *approved* cut-out boxes or cabinets, and when located in wet places or outside of buildings must be mounted in approved "weatherproof" cut-out boxes or cabinets.

Approved metal cabinets should be used in damp places to protect switches and cut-outs. The reason for this is that wood, even if it is thoroughly impregnated with some waterproof compound, is liable, where exposed to continued moisture, to become saturated and thereby become a reasonably good conductor. It is apparent then, that cabinets of metal, which is of course a conductor, are, in so far as insulation is concerned, about as good as wood. The metal cabinets have the further advantage that they are fireproof and that they will not warp out of shape and that the screws holding the cut-outs and switches to them will not loosen. The doors of metal cabinets can be so made that they will close tightly, thereby tending to exclude moisture. They do not warp and bind as wooden ones sometimes do.

19*d*. ¶*I*. SWITCHES, CUT-OUTS, CIRCUIT-BREAKERS, ETC. Time switches, sign flashers and similar appliances must be of approved design and enclosed in *approved* cabinets, except sign flashers mounted as described in No. 83*b*.

Sign flashers, time switches, and similar appliances should always be mounted in cabinets (preferably in metal ones), because they are liable to become disarranged and originate excessive arcs. In most of these devices there is some rotating part which frequently carries current and which is liable, if a screw comes loose, or in case of other accident, to engage with some other metal part of opposite polarity and thereby make trouble. Furthermore, in these devices when they are operating there is nearly always a "drum" which is rotating and which pulls arcs at the different contactors several or many times each revolution. Such arcs, may, under certain conditions, unless the apparatus is properly enclosed, create fires or explosions.

19*e*. ¶*I*. SWITCHES, CUT-OUTS, CIRCUIT-BREAKERS, ETC. Must have the spacing within cabinets or cut-out boxes between the wal'

of the cabinet or cut-out box and current-carrying parts of devices as specified in No. 70.

Questions. Class C. (GENERAL)

73. What provision must be made for insulating wires, not enclosed in approved conduit, molding or armored cable, where they contact with conducting materials such as water, gas, or other metallic piping?

74. Of what lengths must nails or screws be when used to attach (*a*) knobs, and (*b*) cleats?

75. What is the current-carrying capacity of aluminum wire as compared with that of copper wires and cables having a conductivity of 98 per cent?

76. How must conductors be installed when placed in elevator shafts?

77. With what systems of wiring must metal cabinets and cut-out boxes be used?

78. What general requirements must be observed when installing switches and fuses controlling circuits supplying current to motors or heating devices?

79. Excluding fixture work and pendant cord, what is the smallest size wire permissible for inside wiring?

80. Under what conditions must lugs be used for making terminal connections?

81. State the requirements governing the installation of wires crossing metallic pipes in wet or damp places?

82. What is the object of the table of current-carrying capacities given under Rule 18?

83. Under what conditions must approved cut-out boxes be used as housings for switches?

84. What kind of insulation or bushings must be provided when wires are carried through walls, partitions or timbers?

85. State the important requirements controlling the installation of underground conductors where brought into a building.

86. In interior wiring how must wires larger than No. 8 B. & S. gage be supported? If smaller than No. 8 B. & S. gage, how must they be supported?

87. Of what current carrying capacity must the neutral wire be in three-wire systems?

88. Does the CODE permit greater currents in wires having weatherproof and slow-burning insulation than in wires of the same size having rubber insulation? If so why?

89. What kind of wire must be used for a tie wire when a conductor is tied to an insulator.

90. How should porcelain knobs be secured in place?

91. What are the regulations governing the attachment of stranded wires to binding posts?

92. How are underground service entrance tubes installed?

93. Under what conditions may an underground service supply more than one building?

94. How should time switches be installed?

95. What are the installation requirements governing sign flashers?

96. Of what size as compared with the two outside wires must the neutral wire be in direct-current three-wire systems?

97. How should wire splices be made?

98. How should wires be installed in iron pipe bushings when passing through walls?

99. Of what size must the neutral wire be in alternating-current three-wire systems?

100. Under what conditions should solid knobs be used for supporting interior-wiring conductors? Explain.

CONSTANT-CURRENT SYSTEMS

(Rules 20 to 22 inclusive)

Principally Series Arc-lighting

Constant-current systems will not be allowed inside buildings except by special permission.

20. WIRES.

(*See also Nos.* 16, 17, 18 *and* 44. *For construction rules see Nos.* 49 *and* 50)

In constant-current series lighting systems the lighting devices are all connected in series or tandem as shown in Fig. 191. The current in such a series circuit may be impelled by either a direct-current series lighting generator, or by an alternating-current constant-current regulator. Series lighting circuits are used extensively for exterior lighting. Modern

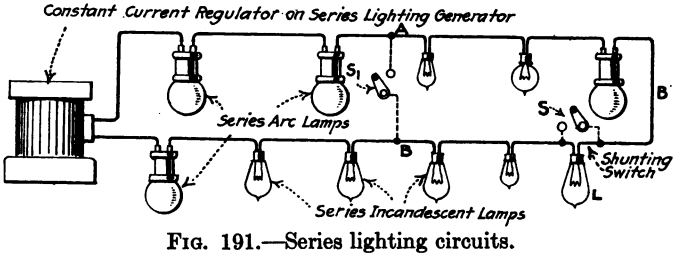


FIG. 191.—Series lighting circuits.

installations are almost invariably alternating-current, which means that in most cases the series lighting circuit is fed through a constant-current regulator. Either a constant-current regulator or a series lighting generator has the property of maintaining the current in the series circuit which it serves practically constant.

EXAMPLE.—Many series lighting circuits operate at 6.6 amp., that is, the regulator or generator which feeds this

circuit is so designed that it will, within the range of its operation, maintain the current in the circuit at 6.6 amp., regardless of the number of lamps connected in series in the circuit. Obviously then, as more lamps are connected into the series circuit, the voltage impressed by the regulator or generator on the circuit is increased. As the number of lamps connected to the circuit is decreased, the voltage impressed by the regulator or generator decreases correspondingly. It is apparent then, that the voltage impressed on a circuit by a constant-current generator or regulator may be very high. The drop across an ordinary series arc lamp is in the neighborhood of 50 volts. Hence if 100 such lamps are connected in series in a circuit and current is impelled through them by a generator or regulator, the generator or regulator must impress 5,000 volts on the circuit.

The currents used in constant-current lighting circuits have been standardized in this country. The following currents are used: 4.0, 5.5, 6.6, 7.5 and 10.0 amp. Probably a current of 6.6 amp. is used more extensively than the others. By 6.6-amp. circuit is meant one, the current in which is at all times (within the limits of its capacity) maintained at an intensity of 6.6 amp. by the regulator or generator serving it.

The disadvantages of constant-current systems for inside installations are that the voltages involved may be, and usually are, excessively high, which engenders excessive fire risk and constitutes serious life hazard.

Constant-current systems are seldom used for interior illumination. A number of years ago series arc lamps and series incandescent lamps were applied for inside lighting, but multiple arc lamps superseded the series arc lamps and multiple incandescent lamps have now largely superseded multiple arc lamps, so that the application of series or constant-current circuits for interior wiring is now limited. Occasionally series tungsten incandescent lamps are used for interior illumination but inasmuch as, on the whole, results as economical and satisfactory and involving less fire risk, can be obtained by using multiple or constant-potential tungsten lamps, the series system is now seldom applied for inside service except in special cases.

20*a*. ¶*I*. WIRES. Must have an *approved* rubber insulating covering.

Approved rubber insulation is required on interior conductors in constant-current systems for the reason suggested above, namely, that the voltage between the conductors of a constant-current system and ground may be very high, which renders it imperative that the most effective insulation obtainable should be applied. *Rule* 50 outlines the specifications for approved rubber-insulated conductors for different operating voltages.

20*b*. ¶*I*. WIRES. Must be arranged to enter and leave the building through an *approved* double-contact service switch, mounted in a non-combustible case, kept free from moisture, and easy of access to police or firemen.

To cut a series lighting device out of circuit, a shunt is arranged around the device. For example, if the series lighting circuit of Fig. 191 is in operation and it is desired to extinguish the incandescent lamp, *L*, the closing of the circuit through the switch, *S*, would effect the desired result. The resistance of the switch would be so very much less than that of the circuit through the lamp, that, with the switch closed, nearly all of the current in the circuit would pass through it, and practically none would pass through the lamp. Then, to again illuminate lamp *L*, switch *S* would be opened. With lamp *L* shunted out of the circuit the total resistance of the series circuit is decreased by the amount of the resistance of lamp *L* and consequently a smaller voltage at the constant-current regulator or generator would force the constant current, on which the circuit operates (for example, 6.6 amp.) through the circuit. Hence, when lamp *L* was shunted out, the voltage impressed by the regulator or generator would decrease just enough so that the current in the circuit would be maintained at 6.6 amp.—if the circuit is a 6.6-amp. circuit. By closing the switch, *S*, the five incandescent lamps and the one arc lamp contained in the portion of the circuit *ABB* would be shunted out. Obviously a series circuit cannot be opened to extinguish any one lighting device in it, because if the circuit is opened all of the lamps in the circuit would be extinguished.

A double-contact service switch should be provided at every point where a constant-current circuit enters a building. Such a switch has the same function as any service switch, that is, by its operation, the wiring system in the building will be entirely disconnected from the source of voltage. It

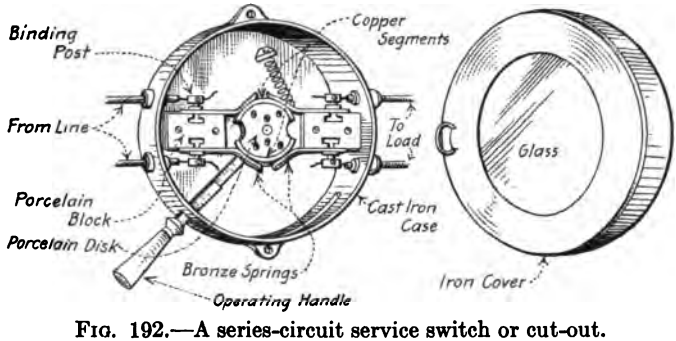


FIG. 192.—A series-circuit service switch or cut-out.

is of great importance that devices be provided whereby firemen can disconnect all wiring within a building from the outside circuits in case of a conflagration.

A double-contact series-circuit service switch is illustrated in Fig. 192. The principle of its operation is illustrated in

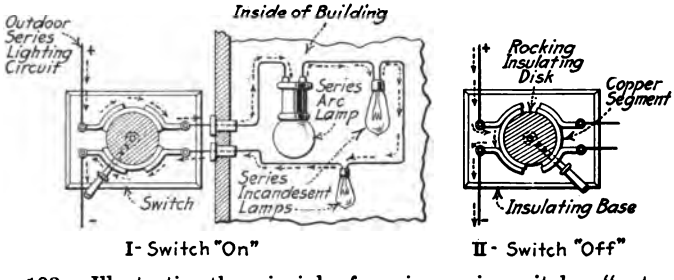


FIG. 193.—Illustrating the principle of a series service switch or "cut-out."

Figs. 193 and 194. These diagrams show one particular type of switch, but indicate the general principle involved in all types. As outlined above, a constant-current regulator or generator tends to maintain the current in the circuit which it is feeding constant under all conditions, hence if a series

circuit is opened, the regulator or generator serving it will tend to drive the normal current of the circuit (for example, 6.6 amp.) through the extremely high-resistance "open." Thereby a very high voltage, probably several thousand volts, will be impressed across the open. When this occurs, a vicious persistent arc results. It is obvious that because of this, series-circuit service switches must be arranged so that they will disconnect the wiring inside of the building without opening the series circuit. Fig. 193, *I*, shows the switch of Fig. 192 in such a position that the current from the outdoor series lighting circuit flows through the arc lamp and the two incandescent lamps in the building as shown by the dotted arrows. Now if the switch is thrown to the position of *II*, no current passes through the circuit in the building—it flows through the copper segment on the rocking disk as shown by the arrows. Note, from Fig. 194 that as the switch is thrown from the position of *I* to that of *II* the series circuit is at no time open, because the copper segment, *S*, constitutes a path between springs *A* and *B*, thus making a complete shunt around the interior wiring, before springs *C* and *D* are disconnected from the outside series circuit.

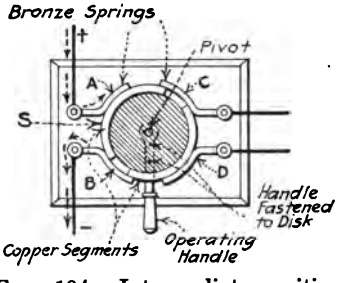


FIG. 194.—Intermediate position of disk of series service switch.

20c. ¶*I*. WIRES. Must always be in plain sight, and never encased, except when *required* by this Department.

Constant-current circuit wires should, in general, never be concealed. The voltages impressed on these circuits may be and are often so high that the conductors should always, in so far as possible, be in plain sight and subject to continual supervision. Obviously, where the wires must pass through floors and partitions it is necessary to conceal them for short distances. In such locations substantial porcelain bushings should be placed around the wires.

20*d*. ¶*I*. WIRES. Must be supported on glass or porcelain insulators, which separate the wire at least one inch from the surface wired over and must be kept *rigidly* at least eight inches from each other, except within the structure of lamps, on hanger-boards or in cut-out boxes, or like places, where a less distance is necessary.

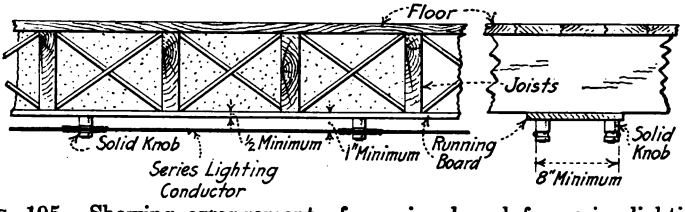


FIG. 195.—Showing arrangement of running board for series lighting circuit.

Constant-current circuit wiring is usually supported on porcelain insulators, which give the clearances between the wire and the surface wired over of at least 1 in., as shown in Fig.

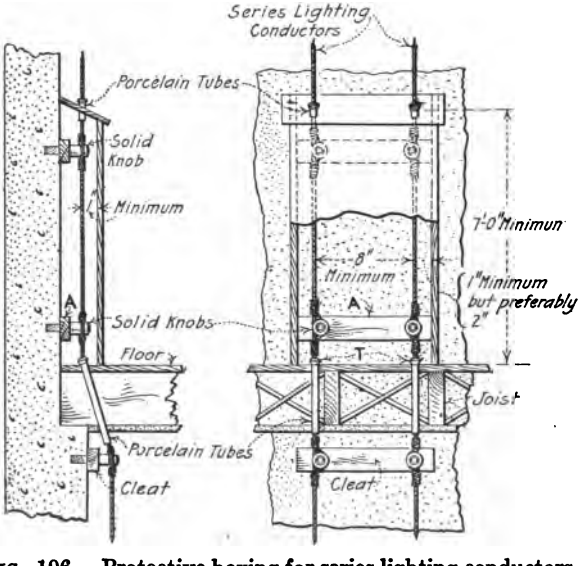


FIG. 196.—Protective boxing for series lighting conductors.

195. In the United States it is the almost universal practice to use No. 6 wire for both interior and outside series lighting

circuits, because smaller wires, although they might carry the current in accordance with the tables of *Rule* 18 without excessive heating and without excessive drop, would be mechanically weak and unsafe. The No. 6 wires are usually tied to solid knobs with tie-wires. Sometimes cleats are used. While wires in low-potential systems may be carried as specified in *Rule* 26*h* as close together as 2½ in. and ½ in. from the surface wired over, experience has shown that it is desirable, because of the high voltages involved, to carry constant-current system wires no closer together than 8 in. and at least 1 in. away from the surface wired over. Where the knobs are supported on a plaster wall, it is always desirable to place under them wooden blocks or cleats as shown at *A* and *A*, Fig. 196, to prevent a side strain on a knob from forcing one side of it down into the plaster, which would, particularly if the knob is located at a corner, permit the wires to sag.

20*e*. ¶*I*. WIRES. Must, on side walls, be protected from mechanical injury by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top (the wires passing through bushed holes), and extending not less than seven feet from the floor. When crossing floor timbers in cellars or in rooms where they might be exposed to injury, wires must be attached by their insulating supports to the under side of a wooden strip not less than one-half an inch in thickness. Instead of the running boards, guard strips on each side of and close to the wires will be accepted.

20*e*. ¶*II*. WIRES. These strips to be not less than seven-eighths of an inch in thickness and at least as high as the insulators.

Boxing on sidewalls for series-circuit conductors may be arranged about as shown in Fig. 196. Such a protective casing should always be provided where it is necessary to carry these conductors through or near the floor on the interior of a building. See Fig. 255 and accompanying description for specific information relating to the construction of protective boxing for low-potential circuits and general information concerning the construction of all protective boxing.

Running-boards or guard strips for constant-current circuit conductors should always be provided where the conductors are carried across floor timbers. Fig. 195 shows one arrange-

ment of a running-board for this service. While the CODE specifies a minimum thickness of ½ in. for these running-boards they should not be less than ⅞ in. thick. (In *Rule* 16*b* it is specified that a screw or nail holding a knob must penetrate the wood a distance equal to one-half the height of the knob. It is apparent that to provide the 1-in. separation required between one of these wires and the surface, the knob for supporting the wire must have a height greater than 1 in., in fact, such knobs are about 1¼ in. high; hence to provide the minimum penetration specified under *Rule* 16*b* the running-board would have to be at least ⅝ in. thick.) Running-boards for these constant-current circuit conductors are of practically the same construction as those described under *Rule* 26*e* for low-potential multiple circuits, except that a greater clearance between wires and between each wire and the surface wired over is necessary with the series-circuit wires. Guard strips for series-circuit conductors can then be made as described under *Rule* 26*e* for low-potential circuits, except that for the constant-current conductors, the greater clearances which are specified above are necessary.

21. SERIES ARC LAMPS.

(*For construction of Arc Lamp see No. 74*)

21*a*. ¶*I*. SERIES ARC LAMPS. Must be carefully isolated from inflammable material.

21*b*. ¶*I*. SERIES ARC LAMPS. Must be provided at all times with a glass globe surrounding the arc, and securely fastened upon a closed base. Broken or cracked globes must not be used.

21*c*. ¶*I*. SERIES ARC LAMPS. Must be provided with a wire netting (having a mesh not exceeding one and one-fourth inches) around the globe and an *approved* spark arrester (see No. 75), when readily inflammable material is in the vicinity of the lamps, to prevent escape of sparks or carbon or melted copper.

21*c*. ¶*II*. SERIES ARC LAMPS. Outside arc lamps must be suspended at least eight feet above sidewalks. Inside arc lamps must be placed out of reach or suitably protected.

21*c*. ¶*III*. SERIES ARC LAMPS. Arc lamps, when used in places where they are exposed to flyings of easily inflammable material, must have the carbons enclosed completely in a tight globe in such manner as to avoid the necessity for spark arresters.

21*c*. ¶*IV*. SERIES ARC LAMPS. "Enclosed arc" lamps, having

tight inner globes, may be used, and the requirements of Sections *b* and *c* above would, of course, not apply to them.

21*d*. ¶*I*. SERIES ARC LAMPS. Where hanger-boards are not used lamps must be hung from insulating supports other than their conductors.

21*e*. ¶*I*. SERIES ARC LAMPS. Lamps when arranged to be raised and lowered either for carboning or other purposes, shall be connected up with stranded conductors from the last point of support to the lamp, when such conductor is larger than No. 14 B. & S. gage.

22. INCANDESCENT LAMPS IN SERIES CIRCUITS.

Incandescent lamps on constant-current circuits, as hereinbefore suggested, are sometimes applied for inside illumination. In modern series-circuit installations, gas-filled tungsten lamps are almost universally used. The series vacuum tungsten lamps have been almost entirely superseded and the carbon series lamps which were once extensively applied are no longer manufactured.

22*a*. ¶*I*. INCANDESCENT LAMPS IN SERIES CIRCUITS. Must have the conductors installed as required in No. 20, and each lamp must be provided with an automatic cut-out.

Each incandescent lamp must be provided with an automatic cut-out. While this rule applies specifically to interior lighting installations, it is also the universal practice to provide every incandescent lamp in a series lighting system with an automatic cut-out or an equivalent arrangement.

The function of the automatic cut-out is to prevent an excessive rise in voltage and a destructive arc across the terminals of the lamp when its filament breaks. As intimated above, an extremely high voltage is impressed across an open in a series circuit. Therefore, if the filament of a lamp which is in service, breaks, a great difference of potential is impressed across the break, creating an arc which is likely to originate a fire.

The operation of the automatic cut-out can be understood from a consideration of Fig. 197, which shows a portion of a series circuit containing two lamps. The cut-out itself, *C*, Fig. 197, and *IV*, Fig. 198, consists of two aluminum disks separated from one another by a leaf of thin silk or similar insulating material. One cut-out is provided for each lamp,

as shown at *C*, Fig. 197, and is inserted between a couple of spring clips with which each lamp is fitted, so that the silk insulating film is in shunt across the lamp terminals. Normally no current passes through the film cut-out. The current passes through the lamp filament, which is in shunt with the cut-out, as shown at *L*, Fig. 197. However, if the filament of a lamp breaks, *B*, Fig. 197, a very high voltage is then impressed across the thin film of silk in the cut-out and the silk breaks down (is punctured by the high voltage) as shown at *D*. The arc that forms through the silk at the instant of the break-down, melts a little of the metal of the disks, which bridges the minute gap, thus completing the circuit. The lamp *B* (Fig. 197) is thereby shunted out of the circuit, but all of the other lamps on the circuit burn.

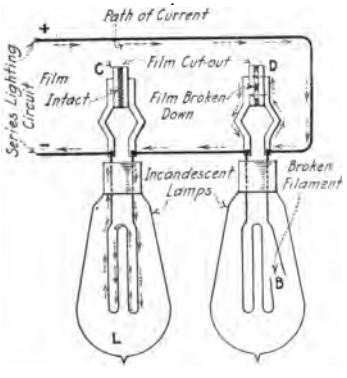


FIG. 197.—Illustrating the operation of the film cut-out.

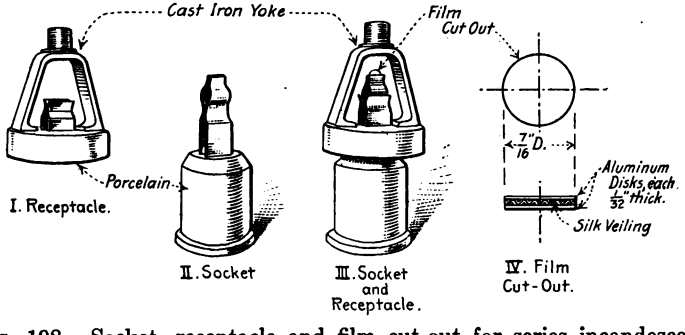


FIG. 198.—Socket, receptacle and film cut-out for series incandescent lamp.

The details of an automatic cut-out device are shown in Figs. 198 and 199, which indicate the construction used by the General Electric Company. The silk veiling used for the

film, *IV*, Fig. 198, is very thin, probably less than 1/100 in. thick. Its thickness has been exaggerated in the illustration. The veiling is cemented in place between the two aluminum disks with insulating varnish.

NOTE (Figs. 198 and 199) that the arrangement of the contact springs is such that the series circuit is never opened when a lamp is being removed or replaced. Hence a lamp can be removed from a receptacle and a film cut-out placed in its clips while the circuit is in operation. Furthermore, note from Fig. 199 that an incandescent lamp can be unscrewed from a socket without opening the circuit because as the lamp is unscrewed, the spring *S* follows it down and closes the circuit at *C* before the lamp base is entirely out of the shell. The film cut-outs are usually designed so that they will break down when a difference of potential of 150 to 200 volts is impressed across them.

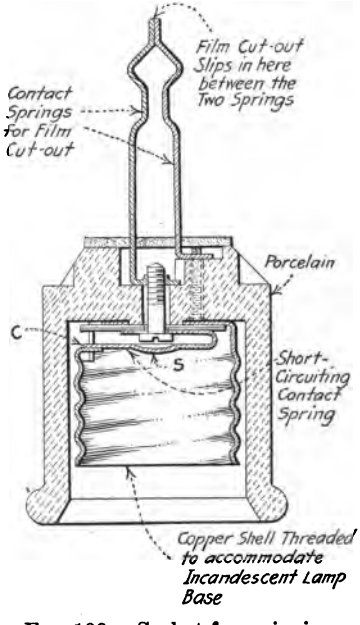


FIG. 199.—Socket for series incandescent lamp. (General Electric Company.)

22*b*. ¶ *I*. INCANDESCENT LAMPS IN SERIES CIRCUITS. Must have each lamp suspended from a hanger-board (see No. 73), by means of rigid tube.

Interior series incandescent lamps should be supported by a stem or tube, that is, they should be held up by a sort of a fixture arranged from a hanger board. The fixture should be so constructed that the entire weight of the lamp socket and accessories will be assumed by the stem. Then no appreciable stress will be imposed on the binding posts or lead wires. This provides insurance against breakage. Furthermore, the conductors to the lamp should be carried inside of the stem, which protects them from interference.

22c. ¶*I*. INCANDESCENT LAMPS IN SERIES CIRCUITS. No electro-magnetic device for switches and no multiple-series or series-multiple system of lighting will be approved.

Electromagnetic switching devices and multiple-series or series-multiple lighting systems fed from constant-current circuits should not be used because experience has shown that they not only are unreliable in operation, but that they may be the source of great fire hazard. See the author's AMERICAN ELECTRICIANS' HANDBOOK for the definition of a series-multiple and a multiple-series system.

22*d*. ¶*I*. INCANDESCENT LAMPS IN SERIES CIRCUITS. Must not under any circumstances be attached to gas fixtures.

Series incandescent lamps should not be attached to gas fixtures, because of the great liability to accident that would result. Gas fixtures are always grounded on the gas pipes connecting to them. Furthermore, there is usually a considerable difference of potential between a constant-current lighting system and ground. Because of this, an arc is liable to occur if a charged series lighting circuit wire contacts with a grounded pipe even if the wire is insulated. On a gas fixture, such an arc might melt a hole in the pipe and ignite the gas.

Questions. Class C. (CONSTANT-CURRENT SYSTEMS)

101. In hanging arc lamps, how far should they be suspended from the sidewalk or floor line?

102. How should suspended arc lamps be supported?

103. Under what conditions may constant-current systems be installed inside of buildings?

104. How must series incandescent lamps be supported?

105. State the requirements which apply to wires of constant-current systems entering or leaving a building.

106. May such wires be encased or concealed? Explain why.

107. State the provisions against fire hazard which must be observed when installing series arc lamps.

108. How many series incandescent lamps be attached to gas fixtures?

109. What special requirements affect the installation of wires for constant-current systems when they cross timbers in cellars or are otherwise subject to interference?

110. What are the minimum spacings permitted between wires of constant-current systems and between the wires and the surface wired over?

111. How must these wires be protected when carried on side walls?

112. What kind of conductors should be used with arc lamps which are arranged for raising or lowering for carboning and why?

CONSTANT-POTENTIAL SYSTEMS

(Rules 23 to 48 inclusive)

GENERAL RULES—ALL VOLTAGES

(Rules 23 to 25 inclusive)

23. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT-BREAKERS).

(*See also No.* 19. *For construction rules see Nos.* 66 *and* 67)

Automatic cut-outs shall be considered as "arcing devices," that is, the fuses or circuit-breakers used for automatic cut-outs may under certain conditions of operation produce violent arcs. On the other hand, the arcs produced when one of these devices operates may be so small as to be of no consequence. To insure safety, however, it is always desirable to assume that the worst possible condition may occur and to adopt adequate precautions in manufacturing and installing automatic cut-outs to prevent the possibility of a fire being originated by the action of these arcs. Note that the four paragraphs under *Rule* 23*a* relate specifically to the automatic cut-outs on service wires.

23*a*. ¶*I*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT BREAKERS). Must be placed on all service wires, either overhead or underground, in the nearest accessible place to the point where they enter the building and inside the walls, and arranged to cut off the entire current from the building. Departure from this rule may be authorized only under special permission in writing.

A cut-out must, except as noted below be inserted in all service wires at the location where conductors enter a building, as shown at *B* in Fig. 200. The function of such an "entrance cut-out" is to insure that the conductors within the building will never be permitted to carry currents greater than those which they can, in accordance with the values of *Rule* 18, safely convey.

EXAMPLE.—In Fig. 200, the conductors *A* extending from the service switch and cut-out are, in the installation shown, of No. 6 rubber-insulated wire. Now, referring to *Rule* 18, a No. 6 rubber-covered wire will carry, without excessive heating, 50 amp., hence 50-amp. fuses are inserted in the entrance cut-out, as shown. The switch should be of at least 50 amp. capacity. Hence, if a current greater than 50 amp. flows for any length of time in the conductors marked *A*, the 50-amp. fuses will melt and open the circuit. It is obvious that fuses

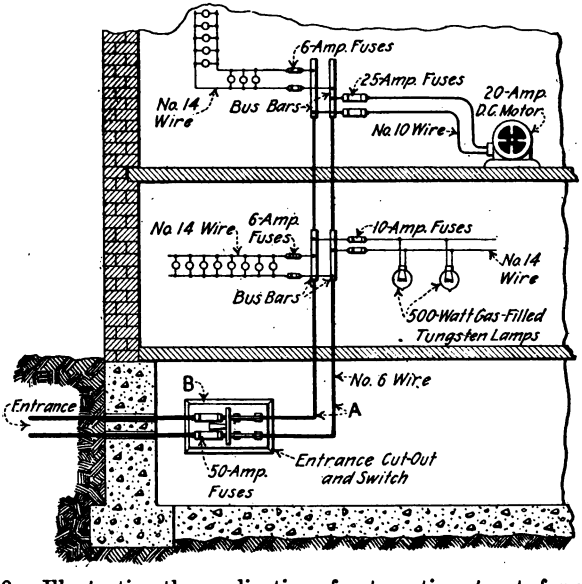


FIG. 200.—Illustrating the application of automatic cut-outs for overload protection.

smaller than 50 amp. may be used in this cut-out *B*, but that it would be unsafe to use fuses of greater capacity.

23*a*. ¶*II*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT BREAKERS). Where the switch required by No. 24*a* is inside the building, the cut-out required by this section must be placed so as to protect it, unless the switch is of the knife-blade type and is enclosed in an *approved* box or cabinet, under which conditions the switch may be placed between the source of the supply and the cut-out.

The entrance cut-out should be so placed that it will protect the entrance switch, as shown in Fig. 201. That is, the fuses

or circuit-breaker should be between the entrance switch and the source of supply, or e.m.f. (unless the entrance switch and cut-out are enclosed in an approved cabinet, as shown in Fig. 202). The reason why the cut-out should be between the

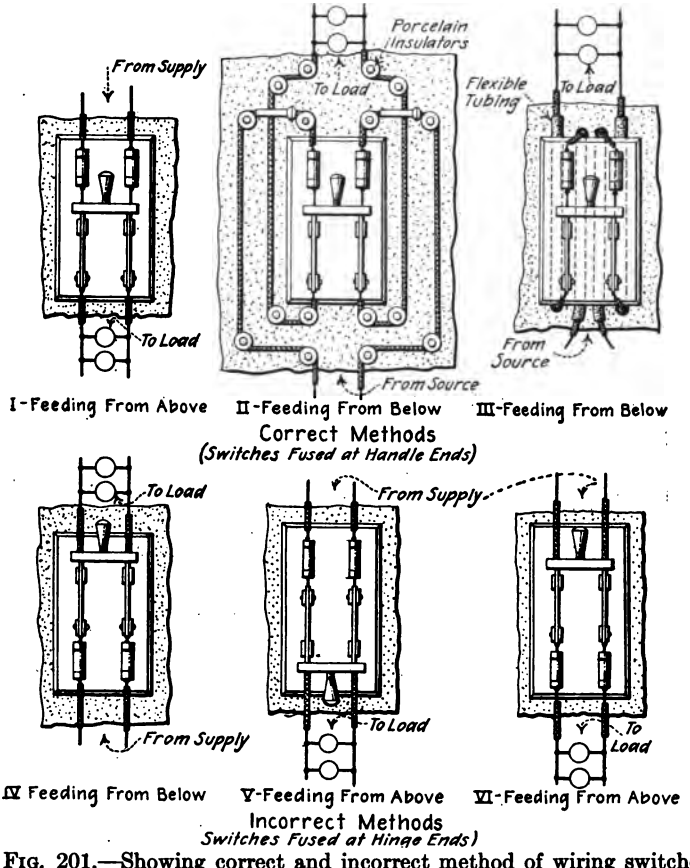


FIG. 201.—Showing correct and incorrect method of wiring switches. (Note, Fig. 202, that switches fused at their hinge ends may be used if installed in iron boxes.)

source of supply and the entrance switch is this: An entrance switch is frequently of the knife-blade type, and in any case, there is always the possibility of a short-circuit occurring between the metal parts of opposite polarity of the entrance

switch. If the entrance cut-out is *not* inserted between the source of supply and the switch, an enormous current might flow through the service wires in case of such a short-circuit and through the entrance switch within the building because the cut-out in the street mains between the entrance switch and the source of e.m.f. might pass a very large current before operating. Where the entrance cut-out is between the source of supply and the switch, the cut-out will, if its capacity has been properly selected, operate before a dangerous current can flow through the service conductors or the short-circuited entrance switch. There are certain other requirements relat-

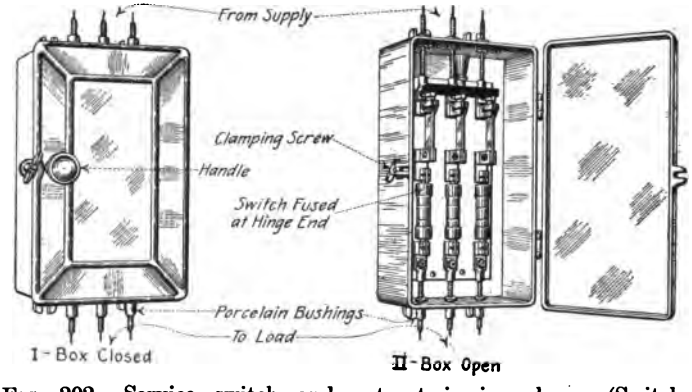


FIG. 202.—Service switch and cut-out in iron box. (Switch is fused at hinge end and fuses *do not* protect switch, but this arrangement is permissible when a knife switch is enclosed in an iron box as above shown.)

ing to the installation of entrance cut-outs and switches which will be discussed in a following paragraph.

Where the entrance switch is of the knife-blade type and enclosed in an approved cabinet the switch may be placed between the source of supply and the cut-out, as shown in Fig. 202. The reason why it is sometimes desirable to arrange the switch and cut-out as shown in Fig. 202 is detailed in a following paragraph. It is obvious that when both switch and cut-out are enclosed in an iron box, the possibility of a fire originating from a short-circuit across the switch blades is remote; hence there is, under these conditions, little objection

to placing the switch between the source of supply and the cut-out.

Where the service entrance switch is not inside of the building the construction illustrated in Fig. 203, *II*, is ordinarily acceptable to wiring inspectors. With this arrangement, while the cut-out does not protect the switch, the switch is outside of the structure where it is accessible, and the cut-out is inside where it is protected from the weather. Where the entrance switch is inside of the building, the entrance cut-out should always protect the switch as shown at *I* unless the switch and cut-out are in an approved cabinet, as suggested in Fig. 202.

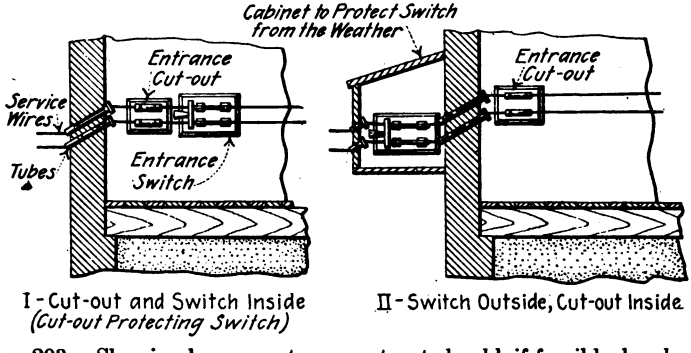


FIG. 203.—Showing how an entrance cut-out should, if feasible, be placed so as to protect the entrance switch.

23*a*. ¶*III*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT BREAKERS). Must not be placed in any permanently grounded service wire.

The fuse should be omitted from the neutral of a three-wire entrance cut-out if the neutral is grounded. (The permanent ground on the neutral should be installed by the central station company on its mains in accordance with the requirements of *Rule* 15.) A consideration of Fig. 204 will indicate that a short-circuit cannot be caused by a ground on the neutral of a grounded neutral three-wire system.

EXAMPLE.—In the illustration (Fig. 204) the neutral of the central station company's outdoor mains is permanently

grounded at G_p and at G'_p. If now, an accidental ground, G_2, occurs on the neutral wire inside of a building, no current will flow through G_2 because there is no appreciable difference of potential or voltage between G_p and G_2 to impel a current between them, that is, between the permanent ground on the neutral of the outside mains and the accidental ground on the neutral of the interior wiring system.

If, now, the accidental ground, G_2, remains on the neutral of the interior wiring system, and an accidental ground, G_3, occurs on one of the outside wires of the outdoor three-wire mains, a current might for an instant flow from the positive wire of the mains via the path G_3G_2 and along the interior wiring neutral ABC to the outdoor main neutral. However, this current would necessarily be relatively very small because the resistance of the path between G_3 and G_p and G_3 and G'_p

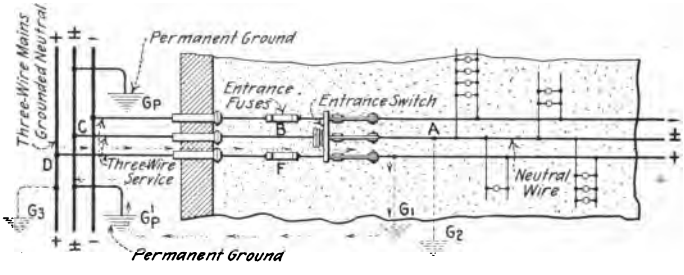


FIG. 204.—Showing why overload protection is not necessary in the neutral wire of a grounded-neutral three-wire system entrance. (Note that it is not permissible to tap branch circuits serving translating devices directly to mains with unfused neutrals unless fuses are inserted in both sides of the branch circuit. See Fig. 222 and discussion.)

would be so very much less than that of the path around through G_2 that practically all of the current would under these conditions flow through the permanent grounds on the main. This current would be so great that it would immediately operate the cut-outs (not shown) protecting the outdoor main and would discontinue it from its source of e.m.f. Service could not be restored until the accidental ground G_3 was cleared.

In fact one of the functions of the permanent grounds (G_p and G'_p) which are installed in accordance with the directions given in *Rule* 15 is to insure protection against the flow of excessive currents in conductors under conditions similar to those just outlined.

Now, assume that a ground G_1 occurs on one of the outer wires of the interior wiring system of Fig. 204. (It is assumed

that the accidental grounds G_2 and G_3 do not now exist.) Then a short-circuit current would flow via the route DF $G_1G'_p$ but if this current exceeded the capacity of the fuse F, that fuse would operate and open the circuit. It would be necessary to clear the ground G_1 before service could be restored. Obviously, then, serious trouble cannot occur, even if the neutral wire is unfused, provided the neutral of the system is thoroughly grounded. Why it is important that the neutral remain electrically intact is explained in a following paragraph.

NOTE.—As a rule all three-wire combination switches and cut-outs of the plug-fuse type have sockets for all three fuse plugs. Such a switch with cut-out is often used as a main-service switch. *Rule* 23*a*, ¶*III*, requires that cut-outs must not be placed in any permanently grounded service wire. This

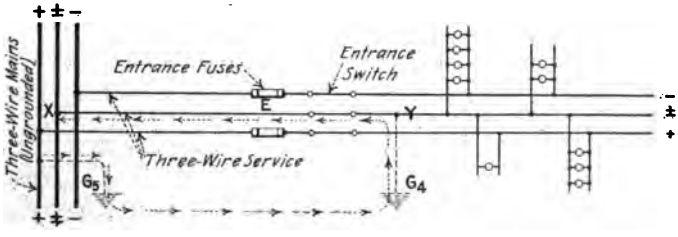


FIG. 205.—Illustrating how an excessive current may flow in the unprotected neutral wire of an ungrounded neutral system.

means that the neutrals of three-wire (but not three-phase) service must be made "solid." To eliminate the neutral fuse, remove the center brass screw and washer from the middle fuse socket and remove the mica insulator also. Then, replace the brass screw and washer and there will be a "solid" electrical connection through the cut-out for the neutral wire. (M. Braun in *Electrical Review*.)

What may occur if the neutral fuse is omitted from a three-wire entrance and the neutral of the system is ungrounded is suggested in Fig. 205. Assume that there is an accidental ground G_5 on one of the outer wires of the three-wire main, and assume that another accidental ground occurs as shown at G_4. A short-circuit current would flow via the path indicated by the dotted arrows. There being no fuse in the neutral at the entrance at E, a current might flow which would be of sufficient intensity to overheat the conductor XY and which

would not be great enough to operate the cut-out protecting the outdoor three-wire mains.

Why the neutral wire should be of the same current-carrying capacity as the outers if the neutral fuse is omitted (and it must be omitted from service wires, *Rule* 23*a*, ¶*III*, if the neutral is grounded) is shown in Fig. 206, *IV*. Where

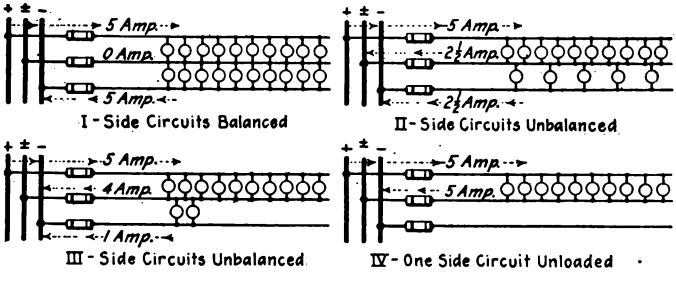


FIG. 206.—Illustrating effect of "unbalance" on three-wire circuit.

there is no load on one of the side circuits or where the fuse in one of the outer wires ruptures, the neutral wire of a three-wire circuit must carry the same current as the outer wire. It is apparent then that it should, if it is unfused, be of the same size as the outer wire to insure safety under such conditions.

A neutral wire if it is ungrounded, may be smaller than the outers if it is properly fused, as shown in Fig. 207. It is apparent that, if the neutral wire is made smaller than the outers and is then so fused that it cannot carry a current greater than that allowable under the terms of *Rule* 18, it cannot be overloaded.

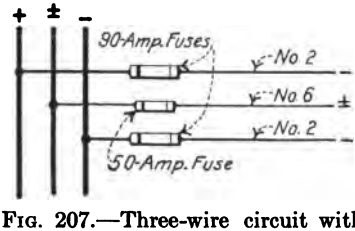


FIG. 207.—Three-wire circuit with outers larger than the neutral.

EXAMPLE.—In Fig. 207, the outside wires are No. 2 rubber-insulated conductors and each is protected by a 90-amp. fuse, since a No. 2 rubber-insulated wire has a safe carrying capacity of 90 amp. The neutral wire is No. 6, having a safe current-carrying capacity of 50 amp. and it is accordingly protected with a 50-amp. fuse.

It is always customary to use a neutral wire of the same size as the outer wires, where the outers are No. 6 or smaller. But where the outers are larger than No. 6 and the neutral ungrounded, it is considered good practice to use for the neutral conductor a wire having approximately two-thirds the cross-sectional area of the outers; then the neutral fuse is selected of corresponding capacity. Sometimes where the neutral is ungrounded and where there is every assurance that excessive unbalance in the side circuits may not occur, the neutral is made one-half the cross-sectional area of the outers and is fused accordingly.

It is essential that the neutral of a three-wire circuit remain electrically continuous in spite of the fact that when the loads on the side circuits of a three-wire system are balanced as shown in Fig. 206, *I*, the neutral carries no current. The

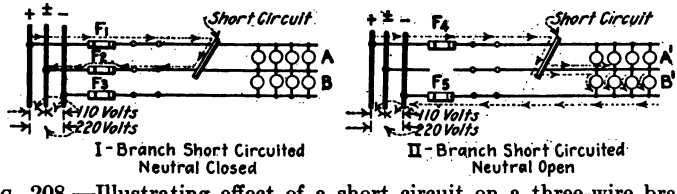


FIG. 208.—Illustrating effect of a short circuit on a three-wire branch circuit.

examples which follow show that when a three-wire circuit is loaded there is practically always some current in its neutral and they also indicate the importance of maintaining the neutral intact.

EXAMPLES.—It is seldom that this ideal condition of Fig. 206, *I*, obtains. If one side circuit carries a load twice as great as that carried by the other, as at *II*, one of the outer wires will then carry twice the current that flows in the neutral and in the other outer wire. Similarly a greater unbalance will produce a condition of which that indicated at *III* is typical. If one of the side circuits has no load on it, as at *IV*, a condition which occurs if a side-circuit fuse blows, then the neutral wire will carry the same current as that in the outer wire which remains intact. If a short-circuit occurs on one of the side circuits of a fused three-wire circuit, as shown in Fig. 208, *I*, the short-circuit current will take the path indicated

by the dotted arrows, and either fuse F_1 or F_2, or both of the fuses, will operate and disconnect the circuit. If, however, the neutral of a system is open, as shown at *II* (due possibly to the omission of a neutral fuse) a pressure of 220 volts would be impressed on the group of lamps (or other receiving apparatus) at *B* and they would, probably, be burnt out.

23*a*. ¶*IV*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT BREAKERS). In risks having private plants, the yard wires running from building to building are not considered as service wires, so that cut-outs would not be required where the wires enter buildings, provided that the next fuse back is small enough to properly protect the wires inside the building in question.

Cut-outs may be omitted at the entrances of private-plant installations in which case the overload protection for the distribution circuits can be concentrated at the switchboard or some other convenient location as shown in Fig. 209. For

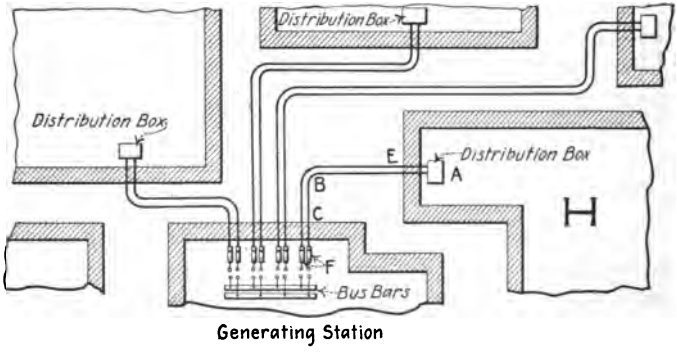


FIG. 209.—Showing how adequate overload protection may, in private-plant installations, be provided at locations other than entrances.

example, cut-out *F* protects the feeder *CBA* in Fig. 209, hence, a cut-out is not required at the point *E* where the feeder enters the building *H*. The function of an entrance cut-out is, as suggested in a preceding paragraph, to prevent the possibility of an excessive current entering the interior wiring system. Where the energy is being supplied from a public service corporation's mains (Fig. 210), it is imperative that a cut-out be placed at the entrance to each building because the fuses (F and F_1) protecting the street mains may be, and fre-

quently are, changed without regard to the carrying capacities of the entrance conductors in the buildings. In a private plant the possibility of thus overfusing entrance conductors is not liable to occur; hence in private plants cut-outs may be located as shown in Fig. 209, and as above described.

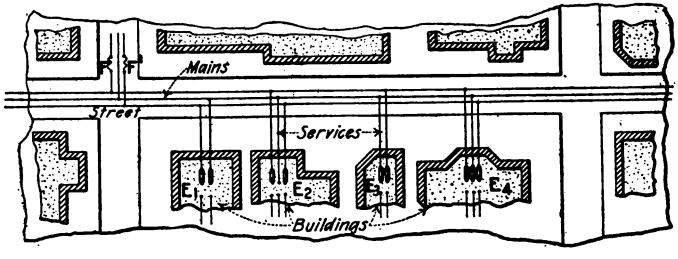


FIG. 210.—Entrance protection in service wires from a public service company's mains.

23b. ¶*I.* AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT BREAKERS). Must be placed at every point where a change is made in the size of wire [unless the cut-out in the larger wire will protect the smaller (see No. 18)].

Where the size of wire of a circuit changes, a cut-out should be provided which will protect the smaller wire. This

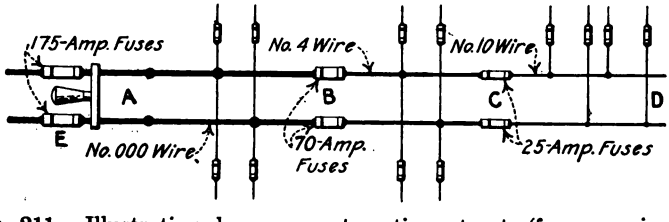


FIG. 211.—Illustrating how an automatic cut-out (fuse or circuit-breaker) should be located where a change in wire size occurs.

principle is illustrated in Figs. 200 and 211. By referring to *Table A* of *Rule* 18 of safe current-carrying capacities, it will be noted that the fuses in the cut-outs shown in each of these two illustrations have been selected of such capacities that they will not pass currents greater than the conductors which are fed through them can safely carry.

EXAMPLE.—In Fig. 211, the main *AB* is of No. 000 which has (rubber insulation) an allowable carrying capacity of 175 amp., hence the fuses at *E* should be of a capacity not greater than 175 amp. There would be no objection to using fuses smaller than 175 amp. capacity for protecting this No. 000 wire. If 175-amp. fuses are not large enough to carry the load fed through this No. 000 wire, a wire of larger size would have to be installed and then fuses of a greater carrying capacity could be used to protect it. Main *BC* is of No. 4 wire; hence 70-amp. fuses are the largest ones through which *BC* should be fed because 70 amp. is the allowable (rubber insulation) current-carrying capacity of No. 4 wire. The main *CD* is of No. 10 wire, so 25-amp. fuses may be used to protect it, since 25 amp. is the allowable carrying capacity of No. 10. If, in Fig. 211, 70-amp. fuses were used at *E*, then the fuses at *B* could be omitted, because 70-amp. fuses would, with a margin, protect *BC* and would obviously then protect *AB*. In other words, a cut-out installation arranged as shown in Fig. 212 would be acceptable, since a cut-out in the larger wire protects the smaller one. Refer to *Rule* 18 for the allowable current-carrying capacities involved.

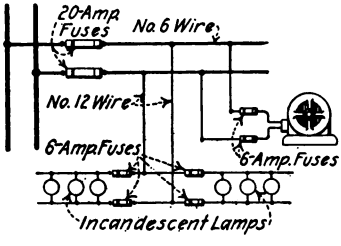


FIG. 212.—Cut-out in a large wire of such a capacity as to protect smaller wires feeding from it.

23b. ¶*II.* AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT BREAKERS). Must not be placed in any permanently grounded wire, except as called for in Section *d*.

FUSING THE NEUTRAL WIRE (Editorial, *Electrical Review* Apr. 17, 1915).—The insertion of a fuse in an electric circuit limits the load which may be placed upon that circuit and limits the duration of a short-circuit between the two leads. It also serves to interrupt the circuit in case of a ground upon the portion protected, provided there is also a ground, intentional or accidental, upon some other portion of the circuit having a potential substantially different from that of the first grounded portion. Except for the latter contingency it would answer just as well to fuse one as to fuse both leads of a two-wire circuit. It was formerly general practice to fuse all three leads of an Edison three-wire circuit, and this practice is still common in many localities. If the neutral wire were not grounded it would be good practice, for the reason

indicated above. But with a grounded neutral there is no necessity for protecting the middle wire against grounds, and the fuses in the outside wires afford protection against short-circuits. In recognition of this fact the 1913 edition of the NATIONAL ELECTRICAL CODE permitted the middle wire of a three-wire system with grounded neutral to be continuous and unfused. The recent revision has gone a step further and made it mandatory to omit this fuse.

This change is an excellent one. The neutral fuse is not only unnecessary but in certain conditions may actually introduce a hazard. The blowing of the neutral fuse may disconnect the middle wire of a portion of a system, resulting not only in unbalancing the voltages on the two sides of the system, but in case of a short-circuit on one side putting double voltage on the other side. This may not only injure lamps and other apparatus through overloading, but may heat some device to the point of creating a fire hazard. Where the neutral wire has a separate ground connection on the load side of the fuse, the above cannot take place, but the result may be that the neutral current will take a return path through the ground connection. This is itself an undesirable condition. English has been better than American practice on this point. In Great Britain general practice is to make solid connection to the neutral, no fuse being introduced in this lead. For some time now grounding of the neutral wire on both direct and alternating three-wire systems has been mandatory in this country, and it is only logical to also make mandatory the omission of the neutral fuse. This is now a CODE rule.

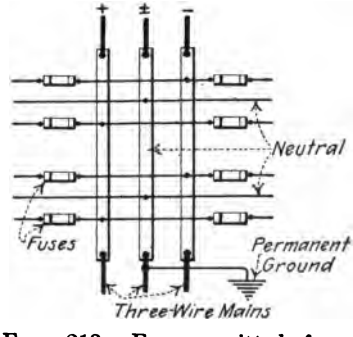


FIG. 213.—Fuses omitted from neutral wires of branch circuits.

The fuse in the neutral wire of any three-wire circuit must be omitted if the neutral is grounded, provided the circuit (as specified in *Rule* 23*d*) does not directly serve a small motor, heating device or incandescent lamp load; see also information under *Rule* 15. Fig. 213 illustrates the meaning of this requirement.

In wiring cut-outs serving branch circuits fed from large mains the wiring is usually arranged as shown in Fig. 214, in

spite of the fact that it does not comply absolutely with the requirements of *Rule* 23*b*, ¶*I*. In Fig. 214, No. 6 wire is used for the portion of the motor branch circuit *BID* which is protected by the fuses, and it is also used for the short sections *AB* and *CD* which are not protected by the fuses. The reason why this construction is usually permitted is that the binding posts on branch circuit cut-outs do not ordinarily have sufficient strength to insure a substantial connection if an endeavor is made to connect large conductors to them. For example, it would probably be difficult to make substantial connections to the cut-out at *BD* if wire the same size as the main, No. 0, were used for the short taps *AB* and *CD*. For the same reason No. 14 wire is used for the short unprotected taps *EF* and *GH* through which the incandescent-lamp branch circuit is fed.

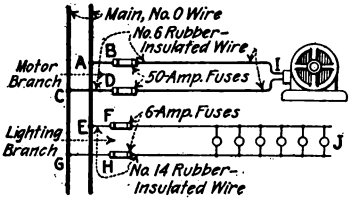


FIG. 214.—Methods of tapping branch circuits from mains.

In wiring circuits as suggested in Fig. 214, one end of a short length of the small branch circuit wire is soldered to the large

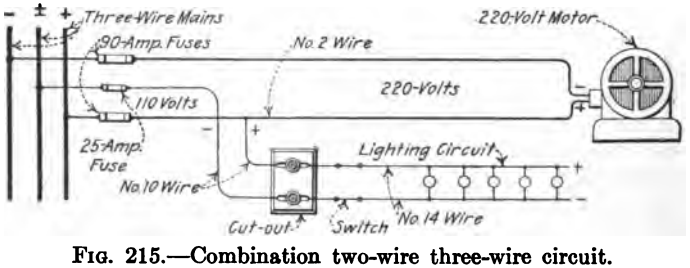


FIG. 215.—Combination two-wire three-wire circuit.

mains and its other end is connected to the branch cut-out terminal by an approved method. The unprotected lengths of the branch circuit wires should be carried by the most direct route to the cut-out and should be as short as possible. Obviously, these unprotected leads should be very carefully located and installed in such a way that they will not be liable

to accidental short-circuits or grounds because of the fact that they are not adequately protected against overload.

A combination two-wire three-wire circuit may be protected against overload as illustrated in Fig. 215. Such an arrangement is frequently desirable where it is necessary to serve a 220-volt motor at the end of a long feeder and to also operate a 110-volt incandescent lighting circuit at the place where the motor is located.

23c. ¶*I*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT BREAKERS). Must be in plain sight, or enclosed in an *approved* cabinet, and readily accessible. They must not be placed in the canopies or shells of fixtures.

Branch circuit cut-outs should be so located as to always be visible or should be installed in approved cabinets (Fig. 216). If the cut-outs are not enclosed and are concealed, there is a possibility of a short-circuit or a ground in one originating a fire which might gain considerable headway before discovery. The local wiring rules in some cities require that all cut-outs be located in approved cabinets. As a general proposition it is believed that it is always much safer to install cut-outs in cabinets, unless the cut-out is of the Edison plug type or of such construction that practically all of the current-carrying parts of the cut-out are protected from accidental contact by insulating materials.

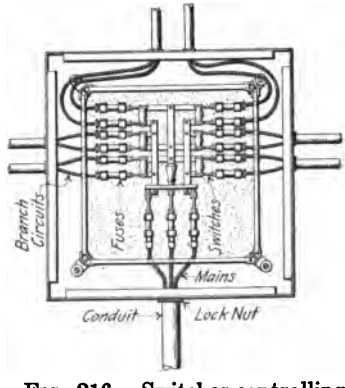


FIG. 216.—Switches controlling branch circuits grouped at a distribution cabinet.

Cut-outs must always be located where readily accessible, so that they can with little effort be re-fused or re-set, if necessary. It is for this reason and also because of the danger of the parts of the cut-out contacting with a fixture that cut-outs should not be located in fixture shells or canopies.

In locations where there is inflammable dust, cut-outs should be enclosed in approved cabinets to prevent the accumulation of the flyings around the conducting portions of the cut-outs. Further information relative to the construction and installation of approved cabinets is given in *Rule* 19*b* and under *Rule* 70. Fig. 216 illustrates typical construction for an approved steel cut-out cabinet. In addition to the cut-outs, branch circuit switches are also installed in this cabinet.

23c. ¶*II.* AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT BREAKERS). Link fuses may be used only when mounted on *approved* bases which, except on switchboards must be mounted in *approved* cut-out boxes or cabinets. A space of at least two inches must be provided between the open-link fuses and metal, or metal lined walls or metal, metal lined or glass paneled doors of cabinet or cut-out boxes.

Open-link fuses, Fig. 217, when they rupture because of an excessive current flowing in them, often "explode," creating

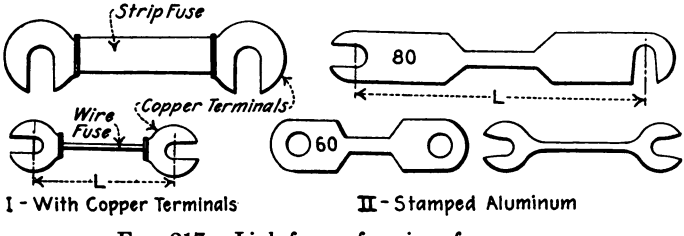


FIG. 217.—Link fuses of various forms.

violent arcs, and throw incandescent metal about. It is evident, therefore, that such fuses should be so located and arranged that they cannot start fires when they "blow." Link fuses will give good satisfaction if they are installed as directed and are maintained by competent mechanics. They are well adapted, because of their low cost, for certain industrial-plant conditions. They should never be installed in residences, office buildings, stores, or in any location where they will be handled by any uninformed persons. Fig. 218 illustrates an approved base for a link fuse, constructed in accordance with the requirements of *Rule* 70. Fig. 219 shows the arrangement and construction of a link-fuse panel mounted

in an approved metal cabinet. The steel door of the cabinet is shown in the illustration.

23*d*. ¶*I*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT BREAKERS). **Must be so placed that no set of small motors, small heating devices or incandescent lamps, whether grouped on one fixture or on several fixtures or pendants (nor more than 16 medium size or 25 candelabra size sockets or lamp receptacles) requiring more than 660 watts, will be dependent upon one cut-out.**

In general, no "small-device" circuit should carry a load in excess of 660 watts, that is, no circuit directly serving incandescent lamps, small motors or small heating devices, should feed a load of a wattage greater than 660. This is one of the most important of the CODE requirements. The intent of this rule is to insure the protection of the sockets, flexible cord,

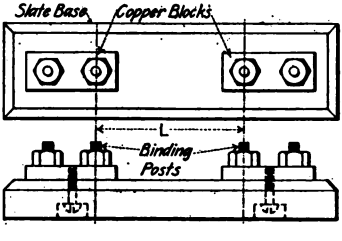


FIG. 218.—Single-pole cut-out block for a link fuse.

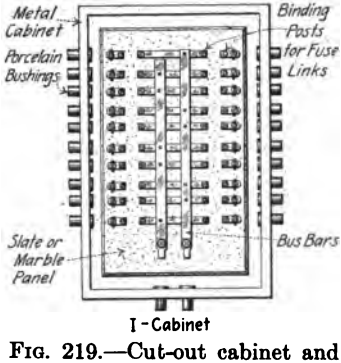


FIG. 219.—Cut-out cabinet and panel for link fuses.

fixture wire and receptacles which are used on these circuits, against excessive overload. On a 110-volt circuit, this requirement is equivalent to specifying that no branch circuit to which small electrical devices are connected shall be protected by a fuse having a capacity greater than 6 amp. However, there are exceptions to this general requirement and fuses of capacities greater than 6 amp. may be used for the protection of small-device branch circuits as outlined in *Rules* 25*a*, ¶*I*, and as noted in the last paragraph. "Exceptions," *Rule* 23*d*, ¶*I*.

Furthermore, by thus limiting the allowable load on any branch circuit the number of incandescent lamps that can be extinguished by the "blowing" of a branch-circuit cut-out is minimized. Refer to Fig. 220. The branch circuit *AB* is of No. 14 wire, the smallest size allowable under the CODE, except for flexible cord and fixture wiring. Now, No. 14 wire has a safe carrying capacity (*Rule* 18) of 15 amp. with rubber insulation and of 20 amp. with other insulations. Hence, on this basis, it might seem permissible to protect this branch circuit *AB* with 15-amp. fuses (assuming it has rubber insulation). However, it should be noted that there are ordinarily connected to branch circuits serving incandescent lamps; heating devices

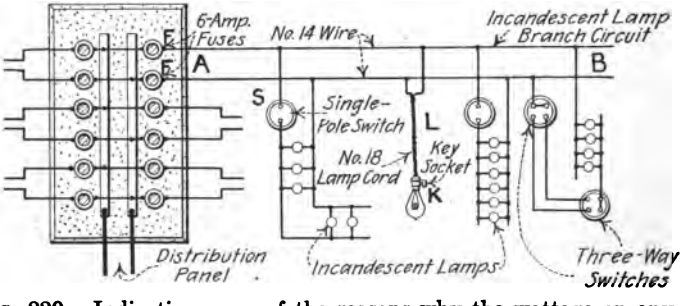


FIG. 220.—Indicating some of the reasons why the wattage on any incandescent-lamp branch circuit should be limited to 660.

and motors, No. 18 flexible cord (*Rule* 51) as at *L*, No. 18 fixture wire (*Rule* 52), sockets, single-pole switches and three-way and four-way switches.

Now referring to *Rule* 18, No. 18 rubber-insulated conductor has a safe current-carrying capacity of only 3 amp.; hence it is apparent that if the circuit *AB* were protected with a 15-amp. fuse, and a ground or partial short-circuit occurred in a No. 18 flexible cord or fixture wire, the No. 18 conductor might be very heavily overloaded and heated excessively before the 15-amp. fuse would blow. Furthermore, the small sockets, receptacles and single-pole switches used on these branch circuits are not designed for carrying large currents or for rupturing any considerable amount of energy.

It is apparent then, that the general ruling which limits

"incandescent-branch-circuit cut-out fuses" to 6 amp. capacity is a wise one. In fact, continued experience has indicated that it is not desirable from any standpoint to exceed this 660-watt limit. Note that in the third paragraph of *Rule* 23*d* it is specified that medium size sockets and receptacles shall, except where used for sign or outline wiring, be considered as requiring not less than 40 watts each.

Exceptions to the rule limiting incandescent-lamp branch circuits to 660 watts are as follows:

1. Where No. 14 wire is carried direct into keyless-sockets installed as specified in *Rule* 23*d*, ¶*II*, 1,320 watts load (32 sockets) may be dependent upon one branch cut-out.

2. In theater outline and large chandelier wiring which satisfies certain requirements, 1,320 watts may be dependent on one cut-out, as specified under *Rule* 23*d*, ¶*VII*.

3. Gas-filled incandescent lamps to a capacity of 1,320 watts may be grouped under the protection of one cut-out, under certain conditions, *Rule* 35*a*.

23*d*. ¶*II*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT-BREAKERS). By special permission, in cases where wiring equal in size and insulation to No. 14 B. & S. gage *approved* rubber-covered wire is carried direct into keyless sockets or receptacles, and where the location of sockets and receptacles is such as to render unlikely the attachment of flexible cords thereto, the circuits may be so arranged that no more than 1,320 watts (or thirty-two sockets or receptacles) will be dependent upon the final cut-out.

Where No. 14 rubber-covered wire is carried direct into keyless sockets or receptacles, an incandescent-lamp branch circuit may serve a load of 1,320 watts, that is, 32 sockets or receptacles. Such a circuit may be arranged as shown in Fig. 221. By carrying the No. 14 wire direct into the sockets, the possibility of No. 18 fixture wire or lamp cord being included in the circuit is eliminated. Furthermore, since on these circuits keyless sockets must be used, a weak "link" that exists in the ordinary lighting circuit, that is, the key socket, is also eliminated. A 110-volt circuit arranged in accordance with these requirements may be fused with 1,320 *watts* ÷ 110 *volts* = 12-*amp. fuses.* No. 14 wire (*Rule* 18) has an allowable carrying capacity of 15 amp.

23*d*. ¶*III*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT-BREAKERS). Except for signs and outline lighting, sockets and lamp receptacles will be considered as requiring not less than 40 watts each, if of the medium size, or 25 watts each if of candelabra size.

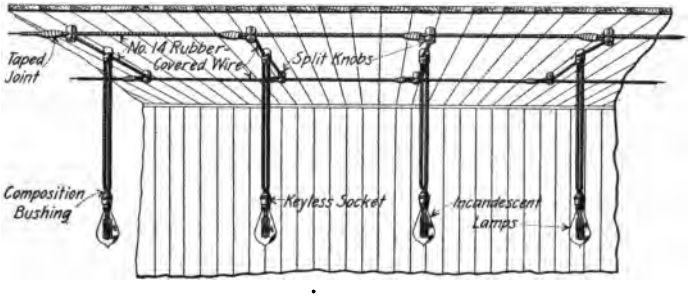


FIG. 221.—No. 14 rubber-covered wire carried directly into keyless sockets.

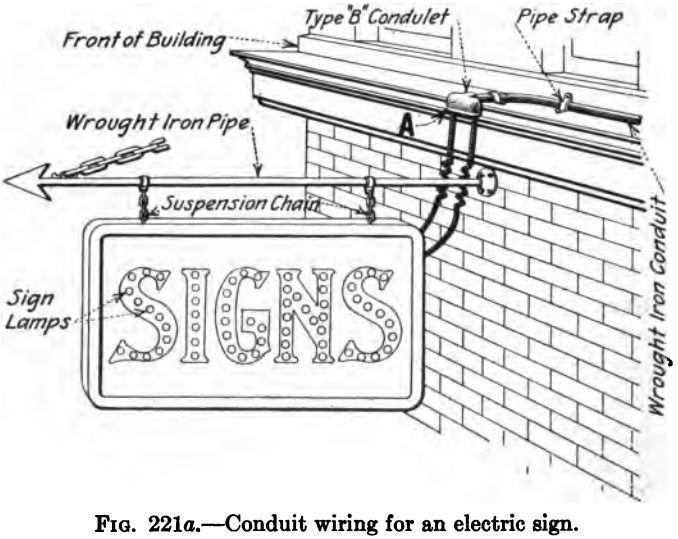


FIG. 221*a*.—Conduit wiring for an electric sign.

An example of conduit sign wiring is shown in Fig. 221*A*. The conductors feeding the sign are brought to a point near it in conduit which terminates in an outlet fitting "*A*." From this fitting the wires are carried to the sign. Pig tails

are provided in the conductors to afford a certain flexibility and to thereby tend to prevent the kinking and breaking of the conductors.

Ordinarily it is assumed that each medium-size socket or receptacle on an incandescent lighting circuit represents a load of 40 watts. It was on this basis that the specification of the first paragraph of *Rule* 23*d*, wherein 16 sockets or receptacles are allowed on an incandescent lighting branch circuit, was determined. That is, 660 *watts* ÷ 40 *watts* = 16½. Since it is not possible to have a half a socket, the number of sockets for a branch circuit was limited to 16. Examples of sign and outline lighting are shown in Figs. 221*a* and 376 respectively.

23*d*. ¶*IV*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT-BREAKERS). Receptacles for attachment plugs rated at not over 660 watts each may be connected to ordinary branch circuits, and where so installed will be considered as requiring not less than 40 watts. Heating and other appliances rated not over 660 watts each may be connected to such receptacles only when the normal load in use on the circuit at any time will not exceed 660 watts. A cut-out must be provided for each receptacle rated above 660 watts.

Heating device wiring is discussed under *Rule* 25. Refer to this text for further information relating to the installation of these devices.

23*d*. ¶*V*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT-BREAKERS). All branches or taps from any three-wire system which are directly connected to lamp sockets or other translating devices, must be run as two-wire circuits if the fuses are omitted in the neutral or if the difference of potential between the two outside wires is over 250 volts, and both wires of such branch or tap circuits must be protected by proper fuses.

If fuses are omitted from the neutral, incandescent-lamp branch circuits from three-wire mains must be run as two-wire circuits as shown in Fig. 222. (Note that, *Rule* 23*a*, ¶*III*, the fuse must be omitted from the neutral wire of any grounded-neutral main or feeder.) The wiring of *I* is incorrect because the branch circuit is run as a three-wire circuit, in spite of the fact that the fuse is omitted from the neutral wire. The wiring of *II* in which a three-wire branch circuit is shown

is correct because the neutral of the mains and also the neutral of the branch are fused; fuses would not be permitted in the neutral shown if the neutral were grounded. The wiring of *III* is also correct, indicating the proper method of tapping branch circuits from a three-wire main, having an unfused neutral. Where the neutral is unfused, only two-wire circuits can be tapped from a main and each of the wires of these two-wire circuits must be protected by its own fuse. Note also that if the voltage between the two outside wires of a three-wire circuit exceeds 250, incandescent-lamp branch circuits tapping from the three-wire main must be two-wire circuits, regardless of whether the neutral of the main is fused or unfused.

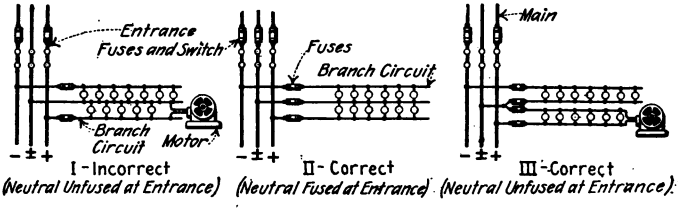


FIG. 222.—Methods of fusing branches or taps which serve translating devices and which feed from three-wire mains.

23*d*. ¶*VI*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT-BREAKERS). The above shall also apply to motors, except that small motors may be grouped under the protection of a single set of fuses, provided the rated capacity of the fuses does not exceed 10 amperes.

Small motors may be grouped under the protection of a single set of fuses if the rated capacity of the fuses does not exceed 10 amp. The words "the above" (*Rule* 23*d*, ¶*VI*) refer specifically to *Rule* 23*d*, ¶*I*. In other words, this fifth paragraph of *Rule* 23*d* means that a number of small motors having an aggregate rating less than 660 watts may be grouped under the protection of one cut-out, provided fuses of a capacity not exceeding 10 amp. are used for protecting the motor branch. The use of 10-amp. fuses instead of the 6-amp. fuses ordinarily applied for the protection of a 660-watt branch is justified in that the larger fuses provide a margin for the starting currents of the small motors. With alternating-current motors

particularly, the momentary starting current may be considerably greater than the normal full-load running current.

23*d*. ¶*VII*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT-BREAKERS). **When 1,320 watts are dependent upon one fusible cut-out, as is allowed in theatre wiring, outline lighting, signs and large chandeliers, the fuses may be in accordance with the following table:**

125 volts or less.....	20 amperes
126 to 250 volts.....	10 amperes

In wiring theater borders, large chandeliers and in outline wiring the standard practice (see text under *Rule* 38 for further information) is to carry No. 12 or No. 14 wire directly to porcelain sockets so that the weak "links" that exist in ordinary incandescent lighting circuits will be eliminated. For this reason incandescent-lamp branch circuits serving theater borders may, on 125-volt circuits, be fused with 20-amp. fuses. This means that No. 12 wire would be used for a circuit so fused, inasmuch as the safe allowable carrying capacity of No. 12 wire is 20 amp. Where the voltage of the branch circuit exceeds 125, but does not exceed 250, the capacity of the fuses protecting it should not exceed 10 amp. that is, for such a circuit, No. 14 wire, which has a safe carrying capacity (*Rule* 18) of 15 amp., would be used.

In wiring for outline lighting (*Rule* 39) it is obvious that the conditions are about the same as those above described for theater wiring, that is, the conductors are carried direct to porcelain keyless receptacles; hence it is reasonable that the same requirements should apply to both cases.

For large chandeliers, keyless sockets are used, the lights on the chandeliers being controlled in groups by switches conveniently located. It is for this reason that the same requirements apply for chandelier lighting as for theater wiring above described.

23*d*. ¶*VIII*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT-BREAKERS). **Fused rosettes may be used only for open work in large mills. *Approved* link fused rosettes may be used at a voltage of not over 125 and *approved* enclosed fused rosettes at a voltage of not over 250,**

the fuse in the rosettes not to exceed 3 amperes, and a fuse of over 25 amperes must not be used in the branch circuit.

The use of link-fuse rosettes is approved for open wiring under certain conditions. The fuse in each rosette must be small enough to protect the lamp socket, flexible cord and fixture wire. Where ceiling rosettes are used, there should be a separate rosette for each pendant and it should be supported independently of the conductors which serve it.

23*e*. ¶*I*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT-BREAKERS). The rated capacity of fuses must not exceed the allowable carrying capacity of the wire as given in No. 18. Circuit breakers must not be set more than 30 per cent above allowable carrying capacity of the wire, unless a fusible cut-out is also installed on the circuit. Where a rubber-covered conductor carries the current of only one A. C. motor of a type requiring large starting current, it may be protected by a fuse or an automatic circuit breaker without time limit device, rated in accordance with Table B of No. 18. The rated continuous current capacity of a time limit circuit breaker protecting a motor of the above type need not be greater than 125 per cent of the motor current rating, provided the time limit device is capable of preventing the breaker opening during the starting period.

Fuses have overload capacity. Link fuses are (*Rule* 68*b*) rated at about 80 per cent. of the current that they can carry continuously, that is, link fuses have about 25 per cent. overload capacity. Enclosed fuses will carry continuously a current 10 per cent. greater than that for which they are rated. For example, a link fuse stamped 100 amp. will carry indefinitely a current of about 125 amp. and an enclosed fuse marked 100 amp. will carry indefinitely a current of about 110 amp. Fuses are so rated as to have overload capacity to insure that a fuse will, without rupturing, handle the ordinary fluctuations of current in a circuit. Furthermore, since it requires an appreciable time for a fuse to attain melting temperature, momentary currents, of intensities much greater than the fuse ratings, will not "blow" the fuses. It is evident then that if a conductor of a given size is protected with a fuse of a rating equal to the allowable current-carrying capacity of the conductor given in *Rule* 18, a margin for overload is provided. If it is necessary to prevent the fuses from blowing, to use

fuses larger than dictated by the *Rule* 18 ratings for the protection of a wire obviously the wire will then be overloaded. In such a case either the load on the wire should be decreased or the size of the wire (the load remaining the same) should be increased.

In setting circuit-breakers for the protection of circuits it is justifiable to set the breaker so that it will trip on a current 30 per cent. greater that the allowable current for the conductor as specified in *Rule* 18. The reason for this is that a circuit-breaker is extremely sensitive and will, unless it is equipped with a time-limit device (see description under *Rule* 8c, ¶*V*) respond instantly and open its circuit if a current greater than that for which it is set flows through it. If a circuit-breaker is set to trip on a current a few per cent. greater than the allowable current for the conductors of the circuit, it is likely that it would trip frequently on momentary overloads. This might result in considerable inconvenience. Such momentary overloading of the circuit conductors is frequently caused by the starting of a motor or the temporary rise in the voltage of a generator due to a sudden decrease in load. If fuses of the proper rating (in accordance with *Rule* 18) are used for protecting the conductors of a circuit, and in addition, a circuit-breaker is provided for the protection of the circuit, the breaker may then be set to trip on any current within its range.

Rubber-insulated conductors serving one alternating-current motor may be fused in accordance with the values of *Table B*, *Rule* 18, that is they may be fused as if they were insulated with material other than rubber. This provision is further discussed under *Rule* 8. Furthermore, if the conductors serving the motor are protected with a circuit-breaker having no time-limit device, then they may also be protected in accordance with *Rule* 18, *Table B*, values. This requirement permits an overfusing or oversetting of about 50 per cent. for rubber-insulated conductors serving only one motor.

23*e*. ¶*I*. NOTE. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT-BREAKERS). In the great majority of cases where A. C. motors of the above type are started by means of autostarters the current-

carrying capacity of wires meeting the rule will not exceed the following percentages of the full load currents of the motors.—

Rated full load current	Percentage
0– 30 amperes	250
31–100 amperes	200
Above 100 amperes	150

23*e*. ¶*II*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT-BREAKERS). For the protection of wires having safe carrying capacities exceeding the rated capacity of the largest *approved* enclosed type fuses, *approved* enclosed fuses arranged in multiple may be used, provided as few fuses as possible are used and the fuses are of equal capacity and provided the cut-out terminals are mounted on a single continuous pair of substantial bus bars. The total capacity of the fuses should not exceed the safe carrying capacity of the wires. This does not apply to motor circuits.

23*e*. ¶*II*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT-BREAKERS). Fixture wire or flexible cord of No. 18 B. & S. gage will be considered as properly protected by 10 ampere fuses.

In protecting No. 18 flexible cord or fixture wire, 10-amp. fuses are acceptable in spite of the fact that No. 18 conductor *Rule* 18) has an allowable carrying capacity of only 3 amp. for rubber-insulated conductor and 5 amp. for conductors with other insulations. The effect of this requirement is to permit the use of No. 18 fixture wires in large chandeliers protected by 10-amp. fuses as specified in *Rule* 23, ¶*VI*. Inasmuch as fixture wire is used only in fixtures where it is protected and encased by the tubing thereof, the possibility of its causing damage, even if it is greatly overloaded, is not nearly so great as if it were exposed.

23*f*. ¶*I*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT-BREAKERS. Each conductor of motor circuits, except on main switchboard or when otherwise subject to competent supervision, must be protected by an *approved* fuse, whether automatic overload circuit breakers are installed or not. Single phase motors may have one side protected by an *approved* automatic overload circuit breaker only, if the other side is protected by an *approved* fuse.

For motor overload protection fuses may be required, even if the circuit is in addition protected by circuit-breakers. The

reason for this is that the setting of circuit-breakers is so easily altered that the attendant may readily, and without authorization, change the setting of a breaker so that it will trip only on a current that will greatly overload the conductors feeding through it. Fuses of different ratings are not readily substituted for one another, hence it is considered that their use in combination with circuit-breakers on motor circuits tends to minimize the abuse above suggested. *Rule* 23*f* specifies that the fuses may be omitted and the circuit-breaker used alone where the breaker is "subject to competent supervision." Wiring inspectors will usually interpret the phrase "*subject to competent supervision*" rather liberally. For this reason motors operating in industrial plants wherein the electrician is always on duty, and in similar locations, are often protected by circuit-breakers alone.

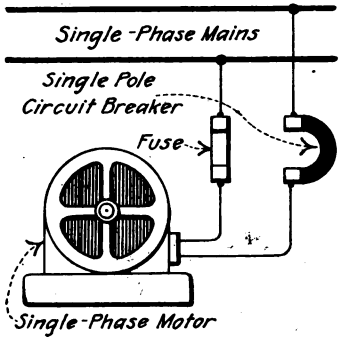


FIG. 223.—Approved overload protection for a single-phase motor.

In protecting single-phase motors against overload, one fuse and a single-pole circuit-breaker are considered adequate if they are installed as shown in Fig. 223.

23*f*. ¶*II*. AUTOMATIC CUT-OUTS (FUSES AND CIRCUIT-BREAKERS). Circuit breakers will be approved for circuits having a maximum capacity greater than that for which approved enclosed fuses are rated.

When overload protection is required in capacities greater than those in which fuses are made, circuit-breakers alone are accepted. The CODE specifies the construction of enclosed fuses only up to and including 600 amp. and it is difficult to purchase fuses of ratings greater than this. Fuses of ratings up to 1,000 amp. are sometimes made. Therefore, if overload protection of a rating in excess of 600 amp. is required, circuit-breakers alone without the auxiliary fuses, specified under *Rule* 23*f*, first paragraph, are acceptable.

24. SWITCHES.

(*See No.* 19. *For construction of Switches see No.* 65)

24*a*. ¶*I*. SWITCHES. Must be placed on all service wires, either overhead or underground, in the nearest readily accessible place to the point where the wires enter the building, and arranged to cut off the entire current. Departure from this rule may be authorized only under special permission in writing.

Service switches should be placed on all wires where the conductors enter a building, except where the buildings are served from a private plant as discussed below (*Rule* 24*a*, ¶*III*), or where the proper authorities give permission for its omission. The service, or entrance switch, should always be installed in combination with the entrance cut-out described under *Rule* 23*a*, ¶*I*.

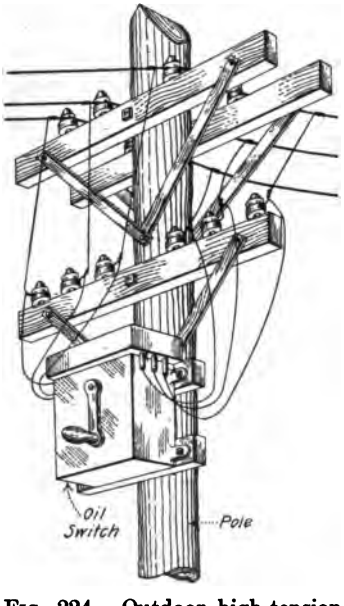


FIG. 224.—Outdoor high-tension service switch.

The function of the service switch is to permit the positive disconnection of the entire wiring system from the source of supply in the case of a fire or other emergency.

Service switches for high-tension wires, in an industrial plant, should be located at the point where the high-tension wires enter the premises. Oil switches, arranged somewhat as suggested in Fig. 224, are frequently installed for this purpose. The handle of the switch should be so arranged that it can be easily reached in case of fire. Sometimes it is desirable to locate such a switch on a platform on a pole with a ladder leading from the ground to the platform. In other instances it is preferable to have an operating rod extend from the handle of the pole switch to the ground. Sometimes a rope

is so arranged between the switch handle and a point a short distance above the ground that the high-tension switch can be operated from the ground by pulling the rope. Such a rope can be run in conduit held to the pole with pipe straps. The conduit should not be in contact with the oil switch casing or any of the wiring.

NOTE.—The term "readily accessible" in *Rule* 24*a*, ¶*I* above is usually interpreted to mean within easy reach from the floor. Certain inspection departments require that the switch be not more than 5 ft. 6 in. above the floor.

24*a*. ¶*II*. SWITCHES. Service cut-out and switch must be arranged to cut off current from all devices including meters. Service switches must indicate plainly whether they are open or closed.

Service switches and cut-outs should be so arranged that they control all interior wiring, that is, if the service switch is opened or if the service cut-out, described under *Rule* 23*a*, operates, all of the electrical conductors and devices associated with the interior wiring circuit should be disconnected from the source of supply. Conditions are frequently such that there is a run of wire between the point where the circuit actually enters the building and the service switch and cut-out which cannot conveniently be thus protected. The interior circuits should always be so arranged that this unprotected run will be of minimum length. In other words, the service switch and cut-out should always be as close as possible to the location where the wires enter the building. The ideal condition is to have them just inside of the point where the wires enter the building in accordance with the specifications under *Rule* 23*d*.

Switches for service entrances should always be selected of such a type that the switch will indicate whether it is open or closed. Such indication is desirable so that a fireman, or any other person, in case of emergency, can ascertain merely by looking at the switch whether or not all of the conductors of the interior wiring circuits are disconnected from the source of supply. Any person can tell by glancing at the position of the blades of a knife switch whether the switch is open or closed. Hence a knife switch may be considered an indicating

switch. Where snap switches, Fig. 225, are used for entrance switches, only those of the type having an indicating dial should be installed. Where knife switches are enclosed in a metal or other approved case with only the handle extending outside of the cabinet, the legends "on" and "off" should be plainly lettered in the proper positions near the slot through which the switch handle extends.

24*a*. ¶*III*. SWITCHES. In risks having private plants the yard wires running from building to building are not considered as service wires, so that switches would not be required in each building if there are other switches conveniently located on the mains or if the generators are near at hand.

Switches need not always be installed at entrances of buildings served by private plants. The reason why such switches may be omitted are similar to those which sometimes render the omission of entrance cut-outs desirable in private plant buildings (*Rule* 23*a*, ¶*IV*). This situation was discussed in a previous paragraph in connection with Fig. 209. In many instances, however, it is desirable, particularly in an industrial plant covering a large area which renders necessary the use of long feeders, to place a switch at the service entrance of each building. Such a switch may be very useful in case of a fire or other emergency to provide for the prompt disconnection of the entire interior wiring system from the source of supply. It will also be convenient in that it provides a means of isolating the interior wiring system when tests are being made. Hence, in isolated plants it may be considered good practice to omit the entrance cut-out, but to install an entrance switch at each building.

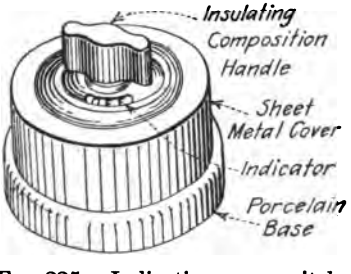


FIG. 225.—Indicating snap switch.

24*b*. ¶*I*. SWITCHES. Must always be placed in dry, accessible places, and be grouped as far as possible. (See No. 19*c*.) Single-throw knife switches must be so placed that gravity will not tend to close them.

Double-throw knife switches may be mounted so that the throw will be either vertical or horizontal as preferred, but if the throw be vertical a locking device must be provided, so constructed as to insure the blades remaining in the open position when so set.

Switches should always be located in dry accessible places. They should always be in dry places because in locations where the atmosphere is moist, corrosion of the metal parts of the switch will occur. The current-carrying contacts may then become so badly corroded thereby that the switch will not close the circuit. Furthermore, some of the metals used in constructing switches appear to disintegrate and become granular and brittle when exposed to moisture. This fact is frequently observed when sheet-brass fittings are installed out of doors. It is obvious that switches should be readily accessible, because if they are not it may be difficult and require considerable time to operate them when they are most needed.

The switches of an installation should, when possible, be grouped. This suggestion follows from the generally accepted doctrine that it is always better to assemble the electrical devices, that require maintenance and which may be operated frequently, at a few locations in the building rather than to scatter them indiscriminately throughout the structure. Fig. 216 illustrates a typical example where all of the switches controlling the branch circuits of an installation are grouped together with the cut-outs in a panel box. Often flush switches for the branch circuits are arranged in a somewhat similar fashion, except that the flush switches can be so mounted that it is not necessary to open the box to operate them.

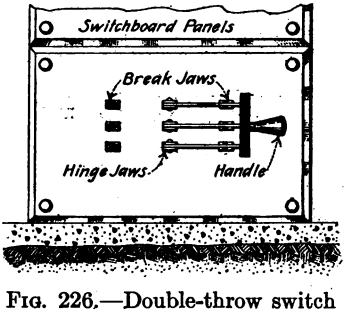


FIG. 226.—Double-throw switch mounted horizontally.

In mounting double-throw knife switches if they are arranged as diagrammed in Fig. 226 it is obvious that gravity

tends neither to open or close the switch; hence such an arrangement is acceptable. If, because of constructional conditions, it is necessary to mount the switch vertically, as shown in Fig. 227, some sort of a safety device should be provided that will prevent the blades from accidentally closing. A simple arrangement which will prevent such accidental closing of a vertically mounted knife switch is shown in Fig. 227. It consists of a small box of wood, or other insulating material, preferably assembled without the use of metallic nails or screws, so

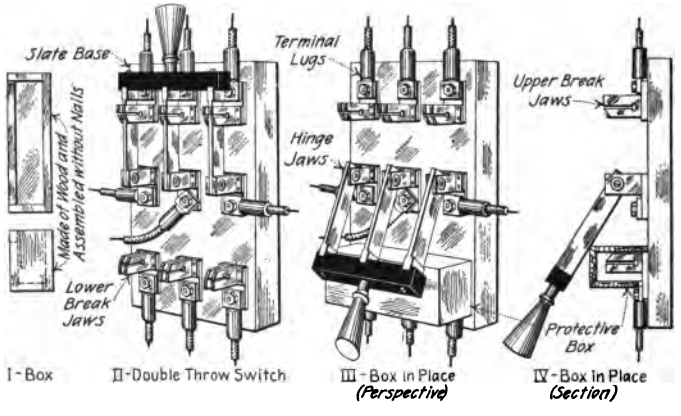


FIG. 227.—Illustrating guard to prevent a vertically-mounted switch from closing accidentally.

proportioned that it will fit over and enclose the lower break jaws of the switch. The construction of the box is shown at *I*. When it is desired to keep the switch open, the box is set over the lower break jaws as shown at *III* and *IV* and the switch blades are pressed down against it, thereby preventing its accidental displacement.

24*b*. ¶*II*. SWITCHES. When practicable switches must be so wired that blades will be "dead" when switch is open.

Switches should be so wired that their blades will not be "alive" when the switch is open for the reason that short-circuits are likely to occur across the blades of an open switch

if it is so wired that the blades are charged when it is open. Such a short-circuit may be due to a screw-driver in the hands of a repair man crossing the blades, or if a repair man is replacing a fuse in the cut-out associated with the switch, the fuse may contact with the two blades.

There are three requirements that should be observed in installing switches. They are:

FIRST: *Where a cut-out is associated with a switch it should be so arranged that it will protect the switch* (*Rule* 23*a*, ¶*II*).

SECOND: *Switches should be so wired that the blades will be dead when the switch is open* (*Rule* 24*b*, ¶*II*).

THIRD: *Switches should be so placed that gravity will not tend to close them* (*Rule* 24*b*, ¶*I*).

Figure 201 illustrates the correct methods of installing single-throw knife switches so that they will meet these requirements. The correct methods are shown at *I*, *II* and *III*, while the incorrect ones are diagrammed in *IV*, *V* and *VI*. From a consideration of this illustration it will be evident that it is impossible to install a switch which is "fused at the hinge end" so that it will satisfy all three of the above requirements. The arrangement of *IV* does not meet the requirements, because the blades of the switch are "alive" when the switch is open. That of *V* is incorrect because the blades are alive when the switch is open and because gravity tends to close the switch rather than to open it. The arrangement of *VI* is incorrect, because the fuses do not protect the switch. In spite of the fact that the arrangements of *I*, *II* and *III* satisfy the three above enumerated requirements, these arrangements all have the disadvantage that the handle of the switch, when the switch is closed, is directly over the fuses; hence it is possible that a person who is closing a switch arranged as shown at *I*, *II* or *III*, and which feeds a short-circuited or heavily loaded circuit, may have his hand burnt. The fuses may blow at the instant that he closes the switch. It is for this and possibly other reasons that, where the switch is inside the building and enclosed in an iron box, a cut-out may be placed between the switch and the source of supply as shown in Fig. 202 and as specified under *Rule* 23*a*, ¶*II*.

24b. ¶*II*. NOTE. Switches. Up to 250 volts and thirty amperes, *approved indicating snap* switches are suggested in preference to knife switches on lighting circuits.

Indicating snap switches are preferable to knife switches on lighting circuits (Fig. 225) because such switches are frequently installed in exposed locations and manipulated by inexperienced persons. Snap switches have all current-carrying parts totally enclosed. This prevents the possibility of accidental shock to the operator and minimizes the liability of fire due to the arc that is formed when the switch is opened. Such an arc may ignite particles of combustible materials on the switch or in the surrounding atmosphere.

24c. ¶*I*. SWITCHES. Single pole switches must never be used as service switches nor for the control of outdoor signs or circuits located in damp places, nor placed in the neutral wire of a three-wire system, except in the two-wire branch or tap circuit supplying not more than 660 watts.

Single-pole switches do not, when open, completely isolate the circuits which they control. It is for this reason that they should not be used for the control of important circuits;

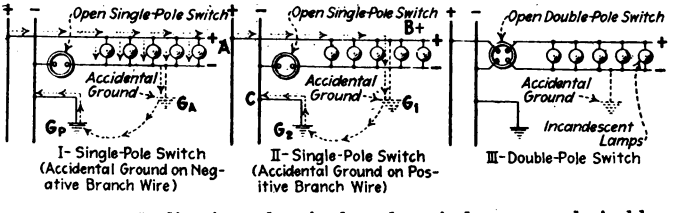


FIG. 228.—Indicating why single-pole switches are undesirable.

they should not be used for service switches for example. For the same reason, they should not be used for the control of circuits that are located out of doors or in damp places because such circuits are particularly subject to grounds.

EXAMPLE.—In Fig. 228, at *I* and *II* are shown two-wire incandescent lamp circuits fed from two-wire supply circuits. The branch circuits are controlled by single-pole switches. In the diagram of *I* there is an accidental ground G_A on the negative wire of the branch circuit. It is assumed that there

is also a ground G_p on the negative wire of the supply circuit. This negative-wire ground might be either an accidental ground or a permanent ground on a three-wire system neutral or on a transformer secondary, provided in accordance with *Rule* 15*b*. A consideration of the illustration will show that due to these grounds there is a closed circuit through the incandescent lamps and the lamps may remain lighted whether the single-pole switch is open or closed. It is obvious that a condition such as that illustrated might, if undiscovered, be a source of considerable trouble and even danger.

At *II* where there is an accidental ground G_1 on the positive branch wire, and also a ground G_2 on the negative feed wire, a short-circuit via the path ABG_1G_2C exists whether the single-pole switch is open or closed. It is possible that the resistance of grounds G_1 and G_2 might be sufficiently high that the short-circuit current might be limited to a small value, say, 5 amp. This current would not be great enough to "blow" the 6-amp. fuse protecting the incandescent-lamp branch circuit, but it might under certain conditions be a source of trouble and possible danger.

As shown in *III*, where a double-pole switch is used, the circuit feeding through the switch is completely isolated from the supply circuit while the switch is open, so that the difficulties diagrammed in *I* and *II* cannot then occur.

Single-pole switches should not be placed in a three-wire system neutral wire, because it is imperative, as outlined in a preceding paragraph (*Rule* 23*a*, ¶*III*) that the neutral wire be continuous when the side circuits associated with it are serving a load. If a single-pole switch were placed in the neutral it might be possible to open the neutral, the side circuit wires remaining closed, in which case the condition illustrated in Fig. 208, *II*, might occur.

Single-pole switches should not be used in the wire of a two-wire branch that connects to the neutral of a three-wire system. The reasons for this are diagrammed in Fig. 229. At *A*, a single-pole switch is cut in the branch-circuit wire which taps to the neutral. Now, even if this single-pole switch is open or closed and an accidental ground (G_1) on the positive branch wire occurs, there is a circuit through the lamps as shown by the dotted arrows, because the neutral of a three-wire system is nearly always (*Rule* 15*a*) grounded per-

manently as at G_p. If in circuit A there is no ground at G_1 but there is an accidental ground G_2 on the other side of the circuit, then a short-circuit current will flow via the path indicated by the full-line wavy arrows. A study of the diagram will indicate that with the single-pole switch cut in the branch-circuit wire (as in branch circuit B) which connects to one of the outer wires of the three-wire main, the lamps will not be illuminated due to an accidental ground on either of the wires of B, nor can one ground on branch circuit B form, in combination with the permanent ground on the neutral, a path for a short-circuit current. However, the troubles suggested in Fig. 228, *I* and *II* might occur on circuit B but could not occur on branch circuit C which is controlled by a double-pole switch. It should be noted that the difficulties indicated in connection with Fig. 228, *I* and *II* are liable

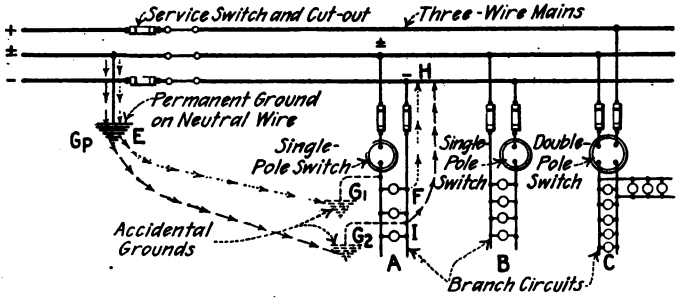


FIG. 229.—Showing why single-pole switches should not be used in the neutral of a three-wire system.

to be encountered only when one of the wires of the two-wire supply system is permanently grounded, because if it is not permanently grounded then two accidental grounds must occur before the situations diagrammed could obtain. Two-wire supply circuits are not always permanently grounded. However, the neutral of a three-wire supply circuit is always permanently grounded, as suggested in Fig. 229, which means that only one accidental ground as G_1 or G_2, Fig. 229, is necessary to cause the difficulties suggested in that illustration.

Single-pole switches should not be used in circuits having loads greater than 660 watts. The reason for this is that it is

desirable to limit the extent of the wiring controlled by a single-pole switch because of the conditions outlined above. Furthermore, experience has shown that ordinary single-pole switches are not capable of continually and positively opening power loads greater than 660 watts. This requirement limits the application of single-pole switches to the control of circuits serving groups of incandescent lamps, small motors or small heating devices, as specified in *Rule* 23*d*, ¶*I*. In other words, no circuit in which a single-pole switch is used should be fused for a current greater than 6 amp. at 110 volts, or 3 amp. at 220 volts. Single-pole switches should never under any conditions be used as service switches or for the control of outdoor wiring (*Rule* 24*c*, ¶ *I*).

24*c*. ¶*II*. SWITCHES. This, of course, does not apply to the grounded circuits of Street Railway systems.

Grounded street-railway circuits may be controlled by single-pole switches. The situation in regard to the protection of street-railway circuits is further discussed under *Rule* 19*a*, ¶*III*.

24*c*. ¶*III*. SWITCHES. Three-way switches are considered as single pole switches.

Three-way switches are considered as single-pole switches, hence should not be used for the control of circuits having

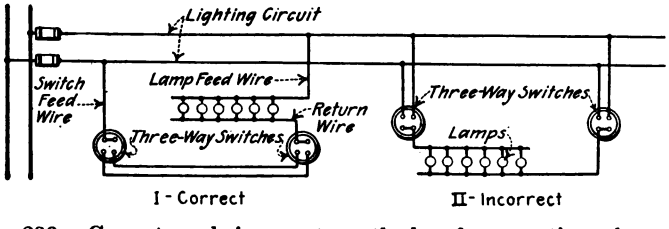


FIG. 230.—Correct and incorrect methods of connecting three-way switches.

loads greater than 660 watts. Furthermore, since a three-way switch is considered as a single-pole switch, it is not permissible to carry conductors of opposite polarity into one three-way switch; therefore, the wiring of Fig. 230, *II*, though it is some-

times used, is incorrect and probably unsafe. The correct method of wiring is shown in *I*.

24*d*. ¶*I*. SWITCHES. Where flush switches or receptacles are used, whether with conduit systems or not, they must be enclosed in an *approved* box constructed of iron or steel, in addition to the porcelain enclosure of the switch or receptacle.

Flush switches must always be enclosed in protective casings. Ordinarily a steel box is used as shown in Figs. 231

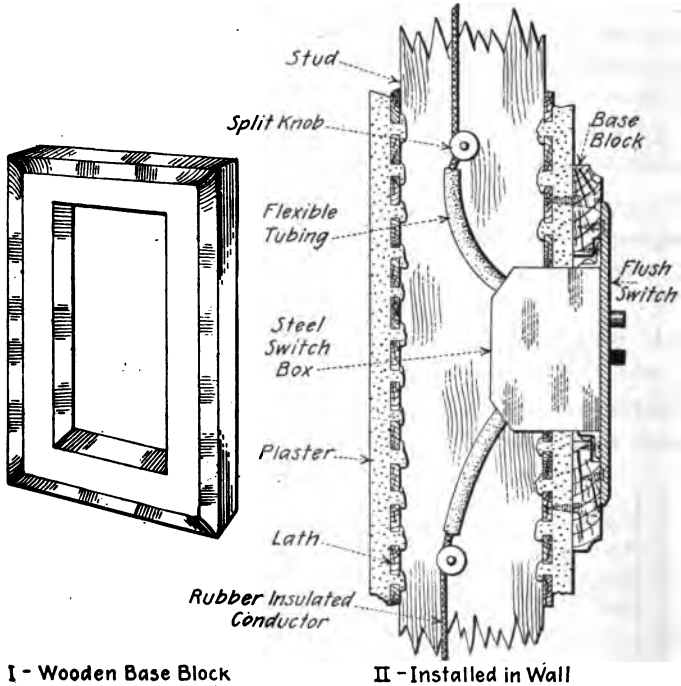


FIG. 231.—Application of wooden base block.

and 232 to give this protection. It is necessary that the flush-switch movement be thus encased to protect it from plaster droppings and to insure that the arcs that are drawn when the switch is operated cannot ignite any of the material within the partition in which the switch is installed.

24d. ¶*II.* SWITCHES. At floor outlets, attachment plugs and receptacles must be enclosed in *approved* floor outlet boxes especially designed for this purpose. Departure from this rule may be authorized only under special permission in writing in cases where attachment plugs and receptacles are not subject to mechanical injury and the presence of moisture is not probable.

Waterproof floor outlet boxes are used as shown in Fig. 233 for the protection of floor outlet receptacles. If no protecting box is used, water may enter and short-circuit the

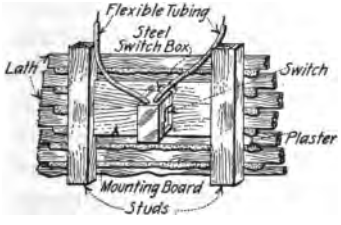


FIG. 232.—Flush switch set in partition encased in an iron box.

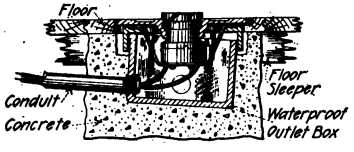


FIG. 233.—A waterproof floor outlet box.

receptacle when the floors are being scrubbed. Furthermore, such a box insures that possible arcs within the receptacle cannot ignite dust or other inflammable material within the floor. Floor boxes of the "adjustable" type illustrated in Fig. 233 are most frequently used. In setting floor boxes, particularly in concrete floors which are in process of construction, it is extremely difficult to level the box correctly and maintain it in alignment. Where an adjustable box is used the main box can be set in the concrete in an approximately level position. Then after the building is practically completed and the receptacles are being installed, the adjustable ring forming the top of the box may be accurately leveled with the finished floor and attached to the main portion of the box which has been set in the concrete.

24e. ¶*I.* SWITCHES. Where possible, at all switch outlets, unless outlet boxes which will give proper support for switches are used, a seven-eighths inch block must be fastened between studs or floor timbers flush with back of lathing to hold tubing and to support switches. When this cannot be done, wooden base blocks, not less than three-fourths inch in

thickness, securely screwed to lathing, or *approved* fittings designed for the service, must be provided for switches.

Substantial supports should be provided for all switches. Where steel outlet boxes are used in combination with conduit wiring, the conduit ordinarily sustains the box rigidly, providing a substantial support. With knob-and-tube wiring it is necessary, and with conduit wiring in frame partitions often desirable, to provide a mounting board or cleat between the studs to support the switch box for a flush switch as shown in Fig. 232. Where a snap switch is to be used, a mounting board should be provided to support it. Where mounting boards have not been provided within the partition prior to plastering, wooden base blocks can be used as shown in Figs. 231 and 234 to support flush and snap switches, respectively. Fig. 238 indicates the proper method of mounting a cast-iron switch box in knob-and-tube wiring.

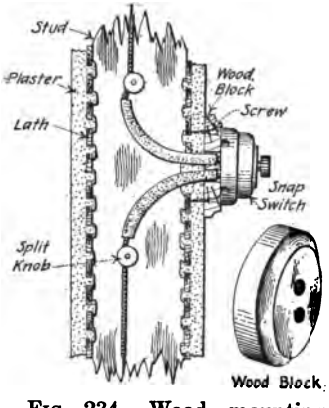


FIG. 234.—Wood mounting block for snap switch on plastered partition (knob-and-tube work).

24*f*. ¶*I*. SWITCHES. Sub-bases of non-combustible, non-absorptive, insulating material, which will separate the wires at least one-half inch from the surface wired over, must be installed under all snap switches used in exposed knob and cleat work. Sub-bases must also be used in moulding work, but they may be made of hardwood or they may be omitted if the switch is approved for mounting directly on the moulding.

Insulating sub-bases should be used for supporting snap switches in exposed knob and cleat work. The function of such bases is to prevent the conductors which enter the switch from contacting with the supporting surface. Small porcelain knobs may be used for thus supporting snap switches as shown in Fig. 235, or instead, molded porcelain fittings (Fig. 236) especially made for the purpose, can be utilized.

Switches in molding-wiring installations should be supported on sub-bases as shown in Fig. 237. Specially made porcelain or wood bases may be used, or the backing of the

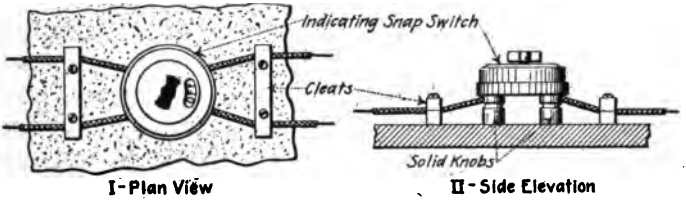


FIG. 235.—Surface snap switch supported on porcelain knobs.

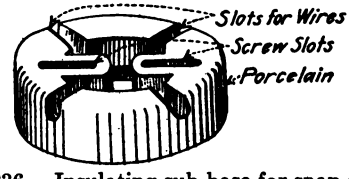


FIG. 236.—Insulating sub-base for snap switch.

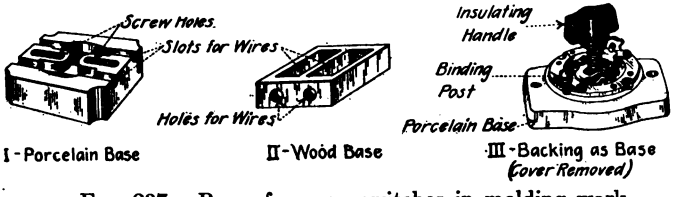


FIG. 237.—Bases for snap switches in molding work.

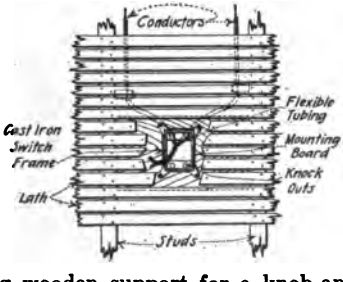


FIG. 238.—Showing wooden support for a knob-and-tube wiring flush switch as it appears before partition is plastered.

molding can be utilized as a base, provided the switch used with it has been especially designed for this construction.

25. ELECTRIC HEATERS.

An electric heater is a device arranged to utilize the heat which is produced by a current of electricity flowing in a conductor. Frequently the "resistor"—the conductor wherein the heat is developed—is wound in a spiral or similar form so that the maximum length (resistance) can be disposed in a minimum space. Among the most frequently applied electric heaters are sad irons, water heaters, room heaters, cooking devices, curling irons and industrial heaters, such as those for glue pots, hat irons and linotype metal. It is obvious that any of these devices may be a source of considerable fire hazard because it must be capable of developing the same heat as would a gas- or coal-heated device serving the same function.

Electric heaters should not be located in dusty or linty places unless adequate precautions are taken to prevent the possibility of fire. Ordinarily, heaters in such locations should be protected in much the same way as are resistance boxes in dusty places, as outlined in *Rule* 4*a*, ¶*II*.

25*a*. ¶*I*. ELECTRIC HEATERS. Each heater of more than six (6) amperes or 660 watts capacity must be protected by a cut-out, and controlled by a switch or plug connector plainly indicating whether "on" or "off" and located within sight of the heater. Heaters of six (6) amperes or 660 watts capacity, or less, may be grouped under the protection of a single set of fuses, provided the rated capacity of the fuses does not exceed ten (10) amperes, or may be connected individually to lighting circuits when the normal load in use on the circuit at any time will not exceed 660 watts.

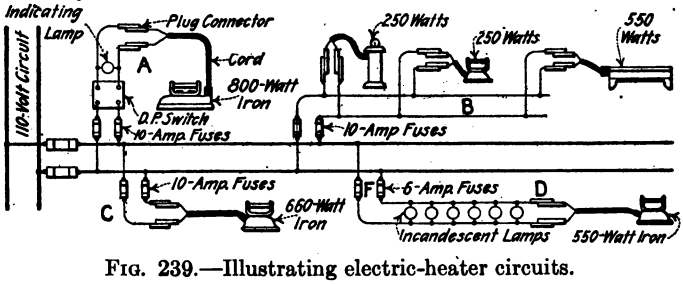


FIG. 239.—Illustrating electric-heater circuits.

The methods of wiring for electric heating devices are diagrammed in Fig. 239. Any heating device requiring power in

excess of 660 watts should be protected by an individual cut-out and controlled by an individual double-pole switch as shown at *A*. Devices each requiring less than 660 watts may be grouped under one set of 10-amp. fuses as shown at *B*. Or, a heating device requiring less than 660 watts may be served from an incandescent-lamp circuit as shown at *D*. In this case, however, the fuses *F* should not be of a greater capacity than 6 amp. because this is the maximum capacity fuse (*Rule* 23*d*, ¶*I*) permissible for an ordinary incandescent lighting circuit. In other words, if heating devices, each of which is of a capacity less than 660 watts, are on circuits from which no incandescent lamps are served, the circuits may be protected by 10-amp. fuses as shown at *C* and *B*, but if there are incandescent lamps on a circuit, the fuse capacity is limited to 6 amp. as shown at *D*.

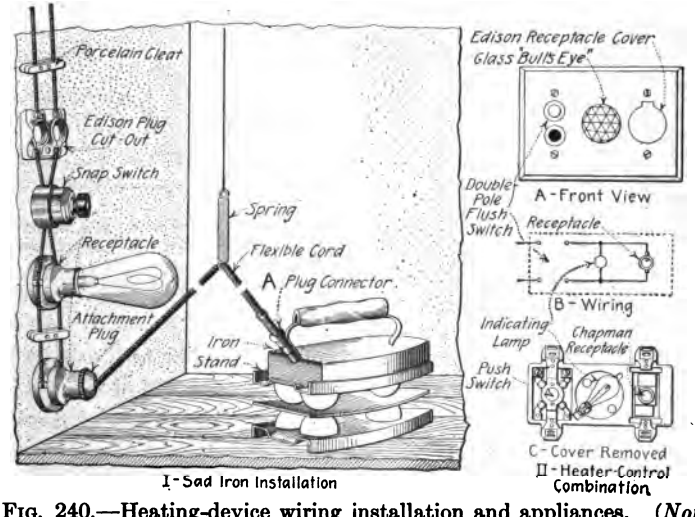


FIG. 240.—Heating-device wiring installation and appliances. (*Note.*—The control combination shown at *C* with cover removed has a switch and receptacle of types different from those illustrated at *A*.)

Indicating or pilot lights, though not required in heating device circuits, are always desirable. Such a pilot light may be connected in multiple in a heater circuit as shown in Fig. 239, *A*, and in Fig. 240, so that when voltage is impressed on

the heater, the lamp will be illuminated. A small lamp, consuming a few watts of power, will serve. The lamp, when lighted, provides an effective visual signal and thereby tends to prevent the heater switch being accidently left closed.

An indicating switch should be used for all large heaters, that is, for heaters requiring more than 660 watts, as shown at *A*, Fig. 239, whether an indicating lamp is used or not. The switch must be in plain sight of the heater. The pilot light referred to above, often used in combination with the heater switch, may be considered as a supplementary indicator.

Special circuits for heating devices (*A* and *B*, Fig. 241) should be used in industrial plants where portable heaters are

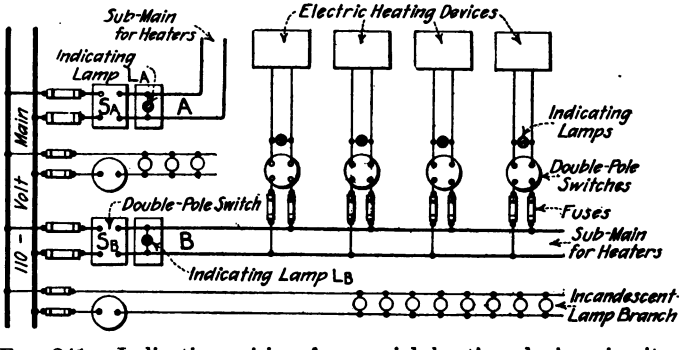


FIG. 241.—Indicating wiring for special heating device circuits.

installed. The circuits should be subdivided and controlled with double-pole switches (S_A and S_B) so that all of the devices in an entire department or instead, a certain group of devices, can be positively disconnected when the department is not in operation and so that the branch circuits to the devices will not be "alive" when no operators are present. A red pilot light (L_A and L_B, Fig. 241) should be associated with the main control switch for each group, even though each individual heater in the group has its own pilot light and switch (which should be located within sight of the heater) so that there will be little likelihood of the group-control switch being left closed accidentally. It is frequently desirable to install special

heating-device circuits in residences, particularly when it is probable that several heaters may be used in the same building.

Domestic heating devices are frequently served through the standard incandescent-lamp sockets. As outlined above, this practice is permissible where the load does not exceed 660 watts, but it is a much better and safer arrangement to serve the devices through special heating circuits. The switches in key sockets and the single-pole switches which are used for the control of the circuits of wattages less than 660 are, in some cases, incapable of prolonged continuous service in heating-device circuits where the power load ruptured by the switches is relatively great.

25*b*. ¶*I*. ELECTRIC HEATERS. Flexible conductors for smoothing irons and sad irons, and for all devices requiring over 250 watts, must have an *approved* insulation and covering complying with the requirements of No. 51*k*.

Flexible cords for heating devices (Fig. 240) where the device requires over 250 watts, must be composed of conductors which are protected from heat and abrasion by an asbestos serving and an outer reinforcing covering of cotton braid or similar material. For devices of wattages less than 250, the ordinary reinforced lamp cord may be used.

25*c*. ¶*I*. ELECTRIC HEATERS. With portable heating devices, *approved* plug connectors must be used, so arranged that the plug may be pulled out to open the circuit without leaving any live parts so exposed as to render likely accidental contact therewith. The connector may be located at either end of the flexible conductor or inserted in the conductor itself.

Plug connections, Fig. 242, are inserted in cords serving portable heating devices, usually in the end of the cord adjacent to the heater, Fig. 240, so that positive means of disconnecting the device will be available whether or not there is a switch in the circuit. Such plug connectors are particularly necessary for devices requiring less than 660 watts, because these devices may be served from a lighting circuit through a keyless socket or possibly through a key socket located out of reach.

25*d*. ¶*1*. ELECTRIC HEATERS. Smoothing irons, sad irons and other heating devices that are intended to be applied to combustible articles, must be provided with *approved* stands.

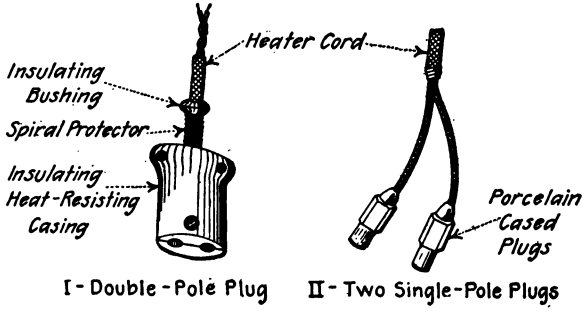


FIG. 242.—Plug connectors for portable heating devices.

Non-combustible stands should be provided for electric irons. A number of fires have been started through the carelessness of an operator in leaving an energized electric iron on a wooden ironing board. Under these conditions, the average electric iron will, if undisturbed for a sufficient period, burn its way through the ironing board. The ironing board or its cloth covering is frequently ignited. It has been found that the ironing surface of an electrically heated iron should operate at a temperature in the neighborhood of 500°F. if it is to be used for ironing damp cloth. The ironing surface of an iron will, if the iron is not used, and its heat is not thereby dissipated, often get red hot in less than 15 min. Automatic cut-outs, arranged for mounting on electric irons, have been designed. The function of such cut-outs is to disconnect the iron from its source of e.m.f. if its temperature exceeds a certain permissible maximum. Such cut-outs have, however, proved unreliable in practice and the general attitude appears

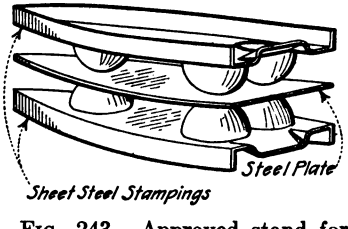


FIG. 243.—Approved stand for an electric iron. (Westinghouse Electric Company.)

to be that these cut-outs tend to increase the fire hazard rather than to reduce it. An electric-iron stand of one type is shown in Fig. 243. Its components are formed from sheet steel. It is arranged to have a maximum of radiating surface. Hence the two air spaces are interposed between the heated surface of the iron that may be on the stand and the plane upon which the stand rests.

Electric-iron installations are usually made about as shown in Fig. 240. While an indicating lamp is not required for an electric iron or any other heating device if it is controlled by an indicating switch, it is considered good practice, and is

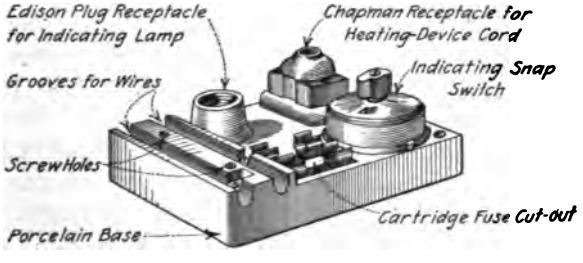


FIG. 244.—An approved heater-control combination for surface wiring, made in 10-amp. and 25-amp. capacities, 250 volts. (Bryant Electric Company.)

undoubtedly desirable, to include an indicating lamp in every installation as shown. Heater-control combinations, Fig. 240, *II* and Fig. 244, are now manufactured in a number of different designs, which renders it uneconomical to assemble a heater-control combination as shown in Fig. 240, *I*, unless it so happens that one of the specially designed combinations is not available. The spring shown in Fig. 240, *I*, is usually included in the electric-iron outfits as furnished by the manufacturers. The function of this spring, which should be very yielding, is to hold the heater cord up out of the way and prevent its dragging over the material being ironed. Another method of installing electric irons that has proven satisfactory in service is described in the author's AMERICAN ELECTRICIANS' HANDBOOK.

25e. ¶I. ELECTRIC HEATERS. Stationary heaters, such as radiators, ranges, plate warmers, etc., must be so located as to furnish ample protection between the device and surrounding combustible material.

Protection for stationary heaters may be provided somewhat as shown in Fig. 245. A shield, composed of two sheets of steel, is interposed between the electric heater and the combustible surface near it. Note that an air space of at least 1 in. should be provided between plates. The plates should be so arranged that there may be a free vertical circulation of air between them, that is, with the construction shown the inner plate, *P*, should not extend entirely to the floor. Frequently alternate laminæ of sheet steel and asbestos, with air spaces between them, can be utilized to advantage in providing protection of this character.

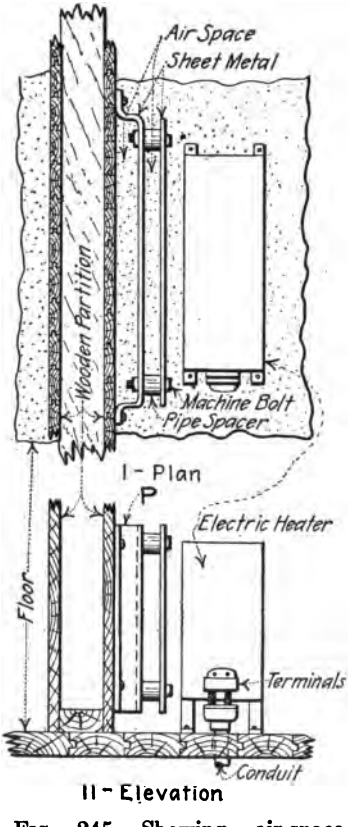


FIG. 245.—Showing air-space screen protecting combustible material from excessive heat.

FIG. 246.—Typical electrical heating device nameplate.

25f. ¶I. ELECTRIC HEATERS. Must each be provided with a nameplate, giving the maker's name and the normal capacity in volts and amperes, or in volts and watts.

Nameplates on heating devices should be provided, Fig. 246, for the same reasons that similar plates are required on motors and generators, that is, so that any person installing

the device can readily ascertain its limitations. Thus a tendency toward overloading, overheating and the consequent fire risk is minimized. Some manufacturers, instead of fastening a separate nameplate on each device, die-stamp the nameplate information on it. Thus any possibility of the loss of the data is prevented.

Questions. Class C. (CONSTANT-POTENTIAL SYSTEMS—GENERAL RULES—ALL VOLTAGES)

113. What requirements govern the installation of fuses and circuit breakers placed on overhead or underground service wires? Explain reasons for these rules.

114. Under what conditions may motors be grouped under the protection of a single set of fuses?

115. What size fuses are considered as safe protection for No. 18, B. & S. gage, fixture wire? Explain in detail and give reasons.

116. What special precautions against fire must be taken when stationary heaters are located near combustible materials?

117. Under what circumstances may single-pole snap switches be used as service switches?

118. Why must cut-outs be placed at points in a circuit where changes are made in wire sizes?

119. In what locations may fused rosettes be permitted?

120. What are the assumed wattage requirements of sockets and lamp receptacles of (*a*) medium size, and (*b*) candelabra size? State the exceptions to this rule.

121. What arrangements are allowable for the protection of wires having carrying capacities greater than the ratings of the largest approved fuses?

122. When must branches or taps from a three-wire system be run as two-wire circuits?

123. Under what conditions may fuses or cut-outs be installed in concealed locations?

124. When 1320 watts are dependent upon one fusible cut-out, what is the permissible rating of the fuses which protect such a circuit?

125. When must heaters be separately controlled and protected?

126. When flush switches are installed, how must they be enclosed?

127. What are service wires?

128. State under what conditions sub-bases must be installed in conjunction with snap switches.

129. State the requirements affecting the use of link fuses.

130. How much above the rated ampere-carrying capacity of the wires which they protect may circuit breakers be set.

131. What are the special cases where the load dependent upon one cut-out may exceed 660 watts?

132. What kind of connectors must be used for portable heating devices?

133. State the conditions under which single-phase motors may have only one side of their circuit protected by an approved automatic overload circuit breaker.

134. May both sides of a circuit enter a three-way switch? Explain.

135. At what locations must switches be placed in overhead or underground service wires?

136. When outlet boxes providing proper support for switches are not used, how should the switches be supported?

137. Give briefly the important general rules covering the installation of service switches.

LOW-POTENTIAL SYSTEMS

550 VOLTS OR LESS

(Rules 26 to 43 inclusive)

Any circuit attached to any transforming device, machine, or combination of machines, which develops a difference of potential between any two wires or between any wire and the ground of not over 550 *volts, shall be considered as a low-potential circuit, and as coming under this class. The primary circuit not to exceed a potential of* 3,500 *volts, unless the primary wires are installed in accordance with the requirements as given in No.* 13, *or are underground. For* 550 *volt motor equipments a margin of ten per cent. above the* 550 *volt limit will be allowed at the generator or transformer.*

26. WIRES.

GENERAL RULES

(*See also Nos.* 16, 17, 18, 20 *and* 27. *For construction rules see Nos.* 49 to 57)

26*a*. ¶*I*. WIRES. When entering cabinets, cut-out boxes or junction boxes, except where they are in conduit, armored cable or metal molding, they must be protected by non-combustible, non-absorptive, insulating bushings, which fit tightly the holes in the box or cabinet and are well secured in place. The wires should completely fill the holes in the bushings, so as to keep out dust, tape being used to build up the wires if necessary. For concealed knob and tube work, or for open work in dry places, *approved* flexible tubing will be accepted in lieu of bushings, providing it extends from the last porcelain support into a wooden cabinet, or is secured to a metal cabinet, cut-out box, junction or switchbox by an *approved* fitting.

The method of bushing conductors entering a cabinet wired in accordance with the open or knob-and-tube method is illustrated in Fig. 247. The holes through which the conductors enter the cabinet should, preferably, be bushed with porcelain tubes as shown at the right of the illustration, but in dry places, flexible tubing can be used as shown at the left.

Flexible tubing may be used for bushing around conductors extending into metal boxes in knob-and-tube installations or

for open work in dry places, provided it extends from the last porcelain support and is held in the box by an approved fitting. Fig. 248 illustrates one form of approved fitting to prevent the end of flexible tubing from pulling off an outlet box. The steel

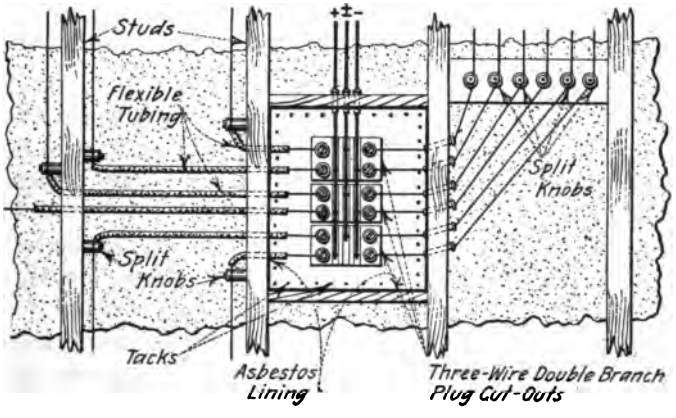


FIG. 247.—Methods of insulating "knob-and-tube" conductors where they enter a wooden cabinet.

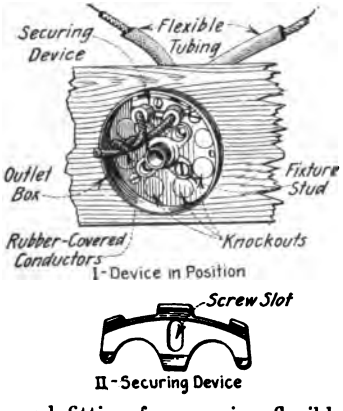


FIG. 248.—Approved fitting for securing flexible conduit ends in metal box.

stamping shown at *II*, is held to the bottom of the box with a screw and is so arranged that, before it is clamped permanently in position, it may be pressed down so that it will "bite"

into the tubing. A number of other devices of somewhat similar construction for performing this same function are manufactured. Other examples of bushings on conductors where the wires enter boxes are shown in Figs. 58*A*, 188, 196, 202, 219, 255 and 275.

26*b*. ¶*I*. WIRES. Must not be laid in plaster, cement or similar finish, and must never be fastened with staples.

Staples should never be used for supporting wires, except signal wires (*Rule* 85). Fig. 159 shows the way *not* to do it.

Conductors should not be laid directly in plaster or cement or allowed to contact therewith, even if the conductors have insulating coverings. Both of these, and similar materials, are fairly good conductors, particularly when moist, and therefore may be sources of grounds or short-circuits if conductors are permitted to touch them. Furthermore, plasters, mortars and cements are alkaline or acid. They may, therefore, prior to drying out, act chemically on the insulating materials on the conductors and impair or destroy them. In certain cases, chemical action of this nature has been sufficient not only to "eat away" the insulation on conductors but to perceptibly corrode the metal of the wire itself.

26*c*. ¶*I*. WIRES. Must not be fished for any great distance, and only in places where the inspector can satisfy himself that the rules have been complied with.

Where it is necessary to fish conductors, they should, where the wiring is in accordance with the knob-and-tube or open-work methods, be encased in flexible tubing, provided the fished portion of the circuit is in a dry location. If it is moist, flexible conduit or armored cable should be employed. Fig. 249 shows an example of an installation where the loom-encased conductors were, in a finished building installation, fished from outlet *B* to pocket *A*. In the author's WIRING OF FINISHED BUILDINGS numerous other examples of fished runs are given and the methods and devices employed in fishing conductors are described in detail.

The lengths of fished runs should be limited because if a long run is fished, it is impossible to ascertain definitely whether

the conductors that have been fished are safely installed. For example, they may be lying on a damp water pipe or in a moist location at some inaccessible point within a partition or ceiling space. The wires should always be encased in flexible tubing before being pulled in.

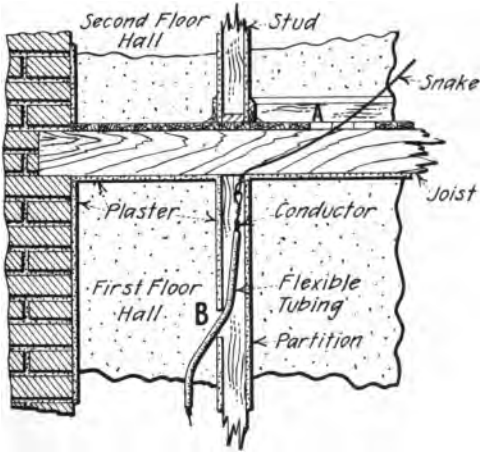


FIG. 249.—Example of fished run.

26*d*. ¶*1*. WIRES. Twin wires must never be used, except in conduits, or where flexible conductors are necessary.

A twin wire is defined in the U. S. BUREAU OF STANDARDS PUBLICATION No. 37 as "*Two small insulated conductors laid*

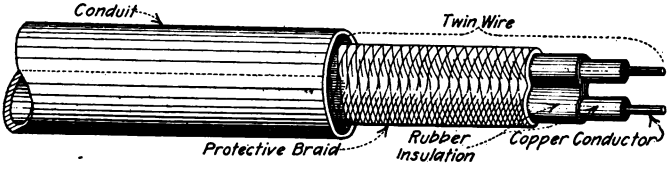


FIG. 250.—Twin conductors in conduit.

parallel, having a common covering." Fig. 250 shows a piece of twin wire in a conduit. Since in wires of this character the conductors of opposite polarity are very close together, it is

obvious that their use should be restricted to places where there will be little likelihood of their causing a fire if a short-circuit occurred between these two adjacent conductors. Another source of hazard lies in the fact that a fire originated by a short-circuit between the two conductors of a twin wire would rapidly follow along the combustible insulation on the conductors. Obviously it would be unsafe to install twin-conductor circuits on knobs or cleats either in exposed or in concealed locations because of the possibility of mechanical interference short-circuiting the wires. When a twin wire is installed within a conduit, the liability of mechanical interference is practically eliminated and furthermore, if a fire did start within the conduit it would be confined within the tube. Flexible conductors are ordinarily considered necessary only with heating devices, pendant sockets, portable lamps, portable motors, stage plugs and adjustable brackets of certain types.

26e. ¶*I*. WIRES. Must, where exposed to mechanical injury, be suitably protected. When crossing floor timbers in cellars, or in rooms where they might be exposed to injury, wires must be installed in *approved* conduit or armored cable or be attached by their insulating supports to the under side of a wooden strip, not less than one half inch in thickness and not less than three inches in width. Instead of the running boards, guard strips on each side of and close to the wires will be accepted. These strips to be not less than seven-eighths of an inch in thickness and at least as high as the insulators.

Guard strips and running-boards are used for the protection of open-work wiring where the conductors must be carried on insulators supported on the lower edges of the timbers in locations where they might be subjected to mechanical interference. Such strips are ordinarily required in basements and in other places where the ceiling is low. In Fig. 251, *I*, each conductor of the circuit is supported on its own running-board which should be at least as heavy as the dimensions indicate. At *II* both the conductors are insulated with cleats which are supported on one running-board. At *III* guard strips are shown. Fig. 252 illustrates a method of supporting a running-board from a ventilating or similar duct. Fig. 253 shows a

"reinforced" running-board for long spans such as those encountered in steel-frame mill buildings.

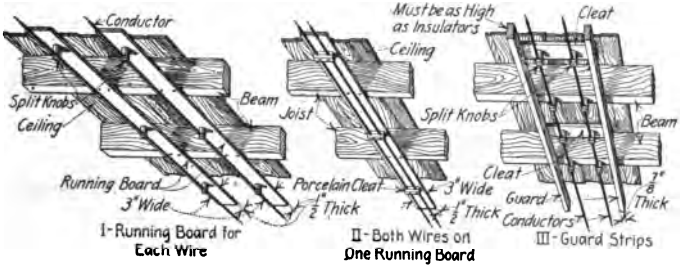


FIG. 251.—Guard strips and running boards for the protection of low-potential conductors where crossing floor timbers and exposed to mechanical injury.

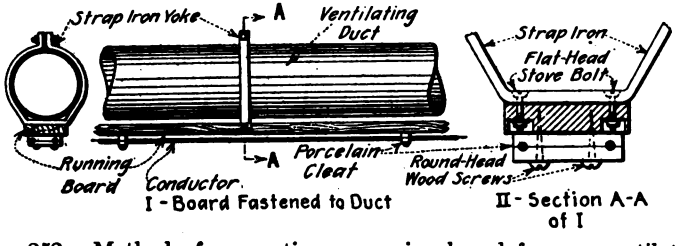


FIG. 252.—Method of supporting a running board from a ventilating duct.

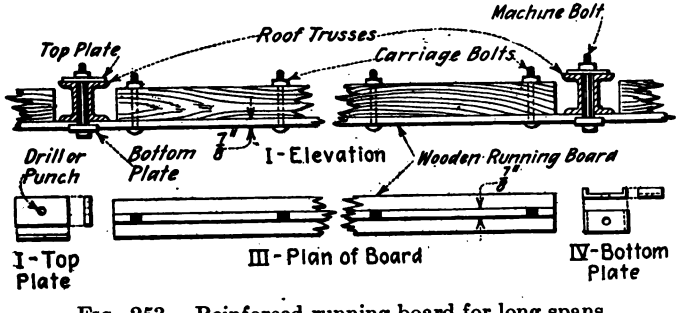


FIG. 253.—Reinforced running board for long spans.

Conduit used to protect conductors crossing floor timbers in exposed locations may be installed as suggested in Fig. 254.

This method is probably the safest and by far the most satisfactory one for mechanical protection in industrial plants or in other buildings where there is considerable traffic and liability to mechanical interference.

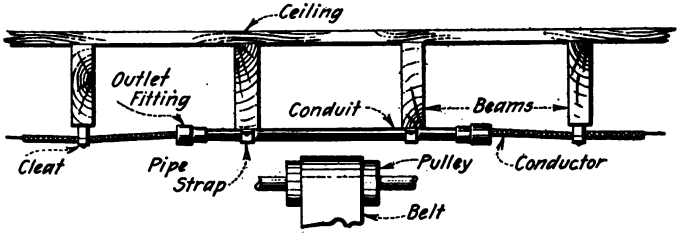


FIG. 254.—Conduit protecting conductors crossing floor timbers.

26e. ¶*II.* WIRES. Protection on side walls must extend not less than seven feet from the floor and must consist of substantial boxing, retaining an air space of one inch around the conductors, closed at the top (the wires passing through bushed holes) or *approved* metal conduit or pipe of equivalent strength.

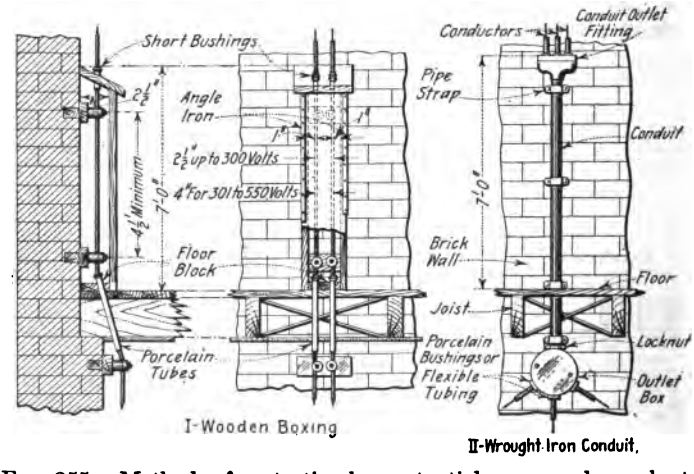


FIG. 255.—Methods of protecting low-potential open-work conductors on side walls. (The distance marked "4½' *minimum*" in the above illustration should read "4½' *maximum*")

Protection for open-work conductors on side walls is illustrated by Figs. 255 and 256. The wooden boxing protection of Fig. 255, *I*, should be made of heavy material. The boards

should be at least ⅞ in. in thickness. Frequently instead of building a box around two cleats fastened to the wall as shown in Fig. 255, *I*, it is desirable to first fasten a "backing board" to the wall and then build the protective boxing around this. The top of the boxing should be pitched as shown so that things will not be laid on it and so that it will not collect dust. A "floor block" at least 2 in. thick should be nailed on the floor at the bottom of the box to raise the head of the tube from the floor level so that scrubbing water will not drain into it. Short porcelain tubes, not more than 1½ in. long for ⅞-in. boards, should be used in the top of the box. If longer tubes are used, they are liable to breakage. In exposed locations the corners of the boxing should be protected with angle iron. The illustration shows the minimum advisable dimensions for protective boxing. These dimensions are in accordance with the requirements of *Rule 26h*. Where it is possible to do so, it is advisable to use greater clearances than those illustrated. The boxing shown is for low-potential conductors. Fig. 196 delineates the construction which should be used for series-lighting-circuit wires.

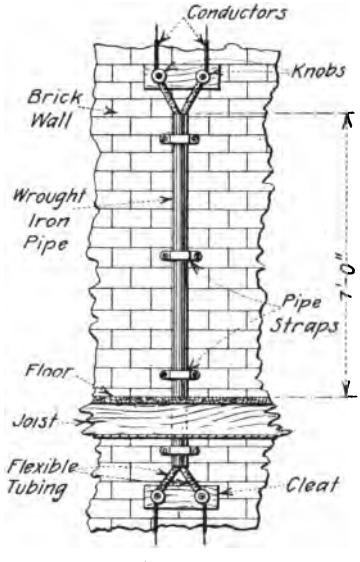


FIG. 256.—Wrought iron pipe used for side-wall protection.

26*e*. ¶*III*. WIRES. When metal conduit or pipe is used, the insulation of each wire must be reinforced by *approved* flexible tubing extending from the insulator next below the pipe to the one next above it, unless the conduit is installed according to No. 28 (Sections *c* and *f* excepted), and the wire is approved for conduit use. The two or more wires of a circuit *each* with its flexible tubing (when required), if carrying alternating current *must*, or if direct current, *may* be placed within the same pipe .

Either conduit or common wrought-iron pipe may be used for side-wall protection as shown in Fig. 255, *II*, and Fig. 256, respectively. However, there are special requirements to be observed with each of these methods of side-wall protection, as will be outlined.

Where wrought-iron conduit is used for side-wall protection and double-braided rubber-insulated conductors are installed within it, no further protection is necessary on the conductors provided each of the ends of the conduit is equipped with an approved outlet box or fitting. At Fig. 255, *II*, the upper end of the conduit is equipped with an approved fitting having a porcelain outlet plate which separates and insulates the wires where they pass through it. At the bottom end of the conduit, an outlet box having three of its knockout holes bushed with porcelain is delineated. The two different methods are shown on the one conduit merely for illustration. Either one of the methods can be used at both ends of the same conduit. Where conduit is used for the side-wall protection of rubber-insulated wire the same rules apply as with any conduit installation except that: (1) it is not necessary to ground the conduit, and (2) the wire to be protected may be installed in the conduit before the mechanical work of the building is completed.

Where a length of conduit for wire protection on side walls or ceilings is more than 10 or 12 ft. long it is the frequent practice with wiring inspectors to then consider the tubing as a conduit system and to require that it be grounded and meet all the requirements of *Rules* 26*n*, *o* and *p*, and 28.

Where ordinary wrought-iron pipe is used for side-wall protection the conductors protected (which may have, *Rule* 26*g*, either rubber, slow-burning-weatherproof, or slow-burning insulation) must be, where they pass through the pipe, protected by flexible tubing, as shown in Fig. 256. The tubing must extend from the next insulator above the upper end of the pipe to the next one below the lower end. The tubing should always extend at least 4 in. beyond each end of the pipe.

26*e*. ¶*III*. NOTE. WIRES. In damp places the wooden boxing may be preferable because of the precautions which would be necessary

to secure proper insulation if the pipe were used. With this exception, however, iron piping is considered preferable to the wooden boxing, and its use is strongly urged. It is especially suitable for the protection of wires near belts, pulleys, etc.

The advantages of the iron-pipe method of side-wall protection are given in the FACTORY MUTUAL BOOK OF RULES, substantially as follows: (1) It requires but little space and is therefore much less subject to interference than is the wooden boxing. (2) It is very strong mechanically, providing ample protection to the conductors against mechanical interference. (3) It provides an excellent ready-made floor bushing which is not easily broken. (4) The amount of combustible material involved is considerably less than with the wooden-boxing method.

26*f*. ¶*I*. WIRES. When run in unfinished attics, or roof spaces, will be considered as concealed, and when run in close proximity to water tanks or pipes, will be considered as exposed to moisture.

Wires run near water tanks or pipes are considered as exposed to moisture and should therefore be installed in accordance with the requirements of *Rule* 26*i*, if the wiring is done by the open-work method. Probably the conduit method is the best one for wiring in damp places. Rigid conduit should be used. In wiring around a water tank in an unfinished attic, as for example, in Fig. 257, the conduit method is the only one permitted. Rigid conduit must be used in the portions of the run exposed to moisture but the intermediate wiring may be installed in flexible conduit or in accordance with one of the other approved methods. Neither metal nor wooden molding (*Rule* 26*l*) is permitted in damp locations.

26*f*. ¶*II*. WIRES. In unfinished attics, or roof spaces, wires are considered as exposed to mechanical injury, and must not be run on knobs on upper edge of joists.

Wiring in unfinished attics or roof spaces is considered as concealed wiring, that is, the conductors must be carried through bushed holes in the timbers just as in the partitions and joists in the lower stories of the buildings. In other words, open-work wiring on knobs or cleats with slow-burning or

slow-burning-weatherproof wire is not permitted in unfinished attics or roof spaces.

Wires should not be carried on knobs on the upper edges of joists in attics or roof spaces because such places are frequently used for storage, and are subject to mechanical interference from workmen; hence there is always the liability of the wires

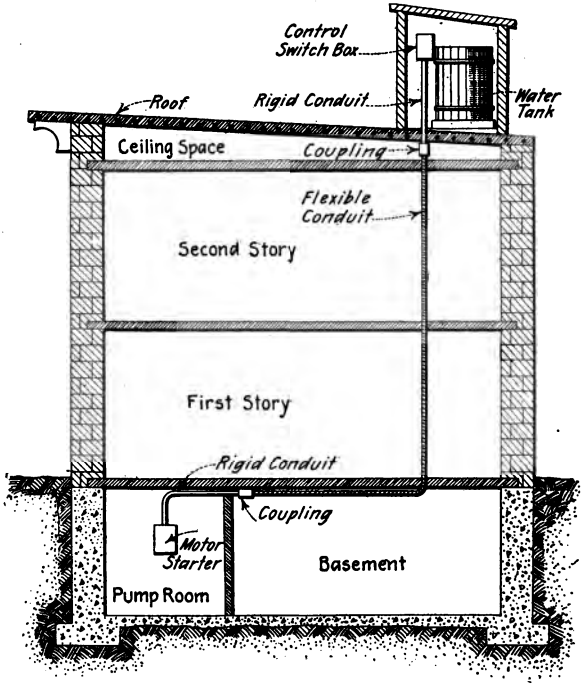


FIG. 257.—Rigid-conduit wiring in locations exposed to dampness.

being disarranged and things being placed on them. The wires should, if the run is along the length of the joist, be supported on knobs nailed on the sides of the timbers. If the runs are at right angles to the direction of the joists the wires should be carried through holes in the joists bushed with porcelain. The word "unfinished" in *Rule* 26*f*, ¶*II*, could be omitted without changing the intent of the rule, because if an

attic is finished (has a floor) it is obviously impossible to run wires on knobs on the tops of the joists.

SPECIAL RULES

FOR OPEN WORK

Exposed or open work is not permitted in all municipalities. In Louisville, Ky. (*Electrical Review*, Dec. 25, 1915, page 1149) open-work wiring is not allowed, the requirements being that all wiring shall be enclosed in metal conduits or in metal molding. This requirement insures that practically all wiring will be installed by responsible concerns and hence, subject to inspection.

In dry places.

26*g*. ¶*I*. WIRES—OPEN, DRY PLACES. Must have an *approved* rubber (Type Letter R. S. for wires smaller then No. 6 B. & S. gage and Type Letter R. D. for wires No. 6 and larger), slow-burning weatherproof (Type Letter S. B. W.), or slow-burning insulation (Type Letter S. B.).

Wire for open-work installation in dry places may have either: (1) approved rubber insulation, (2) slow-burning-weatherproof insulation, or (3) slow-burning insulation. For these conditions, where the voltage does not exceed 550, wire with slow-burning insulation is frequently used, particularly in industrial-plant installations. Its advantages for such service are: (*a*) it costs less than rubber-insulated wire; (*b*) it will not carry fire; (*c*) lint and dust does not collect on the insulating coating of the wire because it has a relatively hard smooth outer surface.

Rubber- and slow-burning-weatherproof insulated wires have rough outer surfaces, which, when warm, become sticky. Hence dust or lint collecting on such wires adheres and is not readily brushed off. Wires having slow-burning insulation should always be used (where the voltage does not exceed 550) where a large number of conductors are grouped together. If wires having rubber or weatherproof insulations are used in such locations, their insulating coverings comprise in the aggregate a relatively large amount of combustible material which increases fire hazard.

26*h*. ¶*I*. WIRES—OPEN, DRY PLACES. Must be rigidly supported on non-combustible, non-absorptive insulators, which will separate the wires from each other and from the surface wired over in accordance with the following table:

Voltage	Distance from Surface	Distance between Wires
0 to 300	½ inch	2½ inch
301 to 550	1 inch	4 inch

The minimum clearances for open-work conductors where the voltage does not exceed 550 are illustrated in Fig. 258. For 300 volts or less the separation between wires must be at least 2½ in. and the wires must be separated at least ½ in.

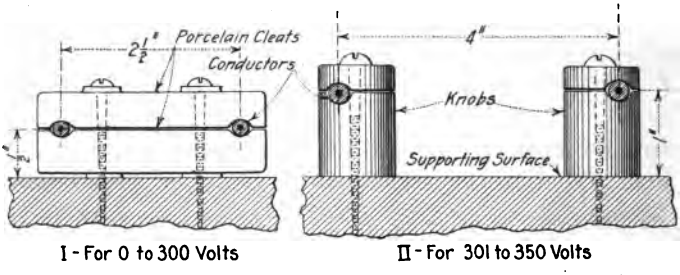


FIG. 258.—Sectional view showing minimum permissible clearances for interior open work in dry places. (Open wires should never be run along and *over* a horizontal surface but they may be run along and *under* supported from—a horizontal surface.)

from the surface wired over. The wires may be carried either on porcelain cleats as shown in the illustration, on solid knobs (*Rule* 16*b*, ¶*I*) if they are bigger than No. 8 and on split knobs if they are smaller, or each wire may be supported by a series of single-wire porcelain cleats. For voltages of 301 to 550 the wires should be at least 4 in. apart, as shown at *II*, and at least 1 in. from the surface wired over. The wires may be carried on either porcelain knobs or cleats provided the provisions of *Rule* 16*b*, ¶*I*, are satisfied.

26*h*. ¶*II*. WIRES—OPEN, DRY PLACES. Rigid supporting requires under ordinary conditions, where wiring along flat surfaces, supports at least every four and one-half feet. If the wires are liable to be

disturbed, the distance between supports must be shortened. In buildings of mill construction, mains of not less than No. 8 B. & S. gage, where not liable to be disturbed, may be separated about six inches, and run from timber to timber, not breaking around, and may be supported at each timber only.

Open-work conductors should ordinarily be supported at least every 4 ft. 6 in., as experience has shown that if the sustaining insulators are located further apart than this, the wires may sag or contact with the supporting surface or with other conductors. Furthermore, if the supports are too far apart the shrinkage of timbers or vibration may materially disarrange the circuits. In locations where the conductors are liable to interference, such as where ceilings are low or in the vicinity of belts or machinery, the insulating supports should not be more than a foot or so apart.

Wires supported at the ceilings in mill buildings may, provided that they are No. 8 or larger, be supported only at each

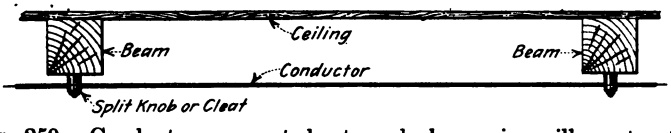


FIG. 259.—Conductor supported at each beam in mill-construction building.

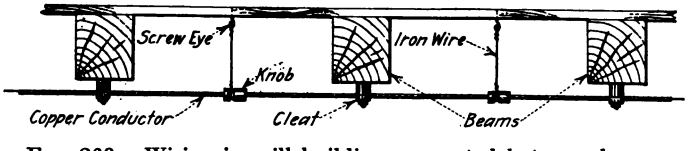


FIG. 260.—Wiring in mill building supported between beams.

beam as shown in Fig. 259, provided they are separated at least 6 in. As indicated in the illustration, there is always a clear space between such beams (they are usually located 8 ft. or 10 ft. apart) in buildings of mill construction, so that the possibility of the conductors contacting with any material between supports is remote. Frequently, it is desirable to arrange intermediate supports as suggested in Fig. 260.

In carrying wires on cleats around timbers, where it is desired to maintain the number of cleats used to a minimum, it is better to locate the cleats which must be supported on the ceiling about 3½ in. from the timber around which the wires are being carried, as shown in Fig. 261, *I*, rather than to set the cleats close to the timber. Where the cleats are too close

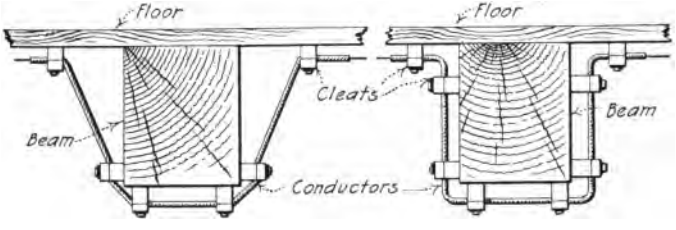


FIG. 261.—Carrying conductors around beams on cleats.

to the beam the vertical portions of the wire are liable to contact with the timber. Probably the best arrangement is to use an additional set of cleats as shown in Fig. 261, *II*, in which case the wires lie reasonably close to the timbers and yet are prevented from contacting therewith.

26*h*. ¶*III*. WIRES—OPEN, DRY PLACES. Must not be "dead-ended" at a rosette, socket or receptacle unless the last support is within twelve inches of the same.

Open-work conductors should not be dead-ended at a rosette, socket or receptacle unless the rosette is within 12 in. of the last support. Fig. 262 illustrates the meaning of this requirement.

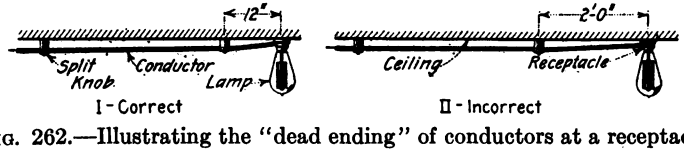


FIG. 262.—Illustrating the "dead ending" of conductors at a receptacle.

In damp places, or buildings specially subject to moisture or to acid or other fumes liable to injure the wires or their insulation.

Wiring in damp places is usually subject to special requirements of the local inspection bureau. It has been found ex-

tremely difficult to install wiring in these locations which will remain serviceable permanently. New devices and methods for service in damp places are constantly being developed so that the local inspectors should always be consulted in regard to the latest and safest methods before an installation is made. Some information concerning damp-place wiring is given in the author's AMERICAN ELECTRICIANS' HANDBOOK.

26*i*. ¶*I*. WIRES—OPEN, DAMP PLACES. Must have an *approved* insulating covering. For protection against water, rubber insulation must be used. For protection against corrosive vapors, either weatherproof or rubber insulation must be used.

26*j*. ¶*I*. WIRES—OPEN, DAMP PLACES. Must be rigidly supported on non-combustible, non-absorptive insulators, which separate the wire at least one inch from the surface wired over, and must be kept apart at least two and one-half inches for voltages up to 300, and four inches for higher voltages.

26*j*. ¶*II*. WIRES—OPEN, DAMP PLACES. Rigid supporting requires under ordinary conditions, where wiring over flat surfaces, supports at least every four and one-half feet. If the wires are liable to be disturbed, the distance between supports must be shortened. In buildings of mill construction, mains of not less than No. 8 B. & S. gage, where not liable to be disturbed, may be separated about 6 inches, and run from timber to timber, not breaking around, and may be supported at each timber only.

Open-work conductors on mill-building ceilings subject to dampness may be installed in accordance with practically the same requirements as apply to similar conductors in dry places specified in and described under *Rule* 26*h*, ¶*II*, and as illustrated in Fig. 259.

FOR MOULDING WORK (WOODEN AND METAL)

(*See No.* 29. *For construction of Mouldings see No.* 60)

26*k*. ¶*I*. WIRES—MOULDING. Must have an *approved* rubber insulating covering (Type Letter R. S. for wires smaller than No. 6 B. & S. gage and Type Letter R. D. for wires No. 6 and larger), and must be in continuous lengths from outlet to outlet, or from fitting to fitting, no joints or taps to be made in moulding. Where branch taps are necessary in moulding work *approved* fittings for this purpose must be used.

Wire for use in molding should have good (approved rubber) insulation because the conductors in molding, particularly in

metal molding, lie close together. Furthermore, metal molding is always grounded; hence the insulation on the conductors in it is all that prevents them from contacting with each other or with ground. Wires having weatherproof or slow-burning insulation will, in most cases give trouble ultimately if they are installed in molding, particularly where subject to dampness.

There should be no joints or splices within a molding system except at outlets, because the insulation on a splice is always inferior to that on the unimpaired conductor and furthermore the bulkiness of a splice frequently, when the wires are in wooden molding, renders it necessary to cut away a portion or all of the tongue (in the molding base) which should always separate the conductors from one another. This weakens the base and may result in short-circuits. Also, experience has shown that there is a tendency on the part of wiremen to leave unsoldered and untaped the joints in molding, if such are made, and they frequently burn the backing when soldering splices.

Approved fittings must be used wherever it is necessary to splice or tap to a wood-molding-wiring conductor. In these fittings the wires are jointed together with screw binding posts, rendering the use of solder unnecessary. See the author's AMERICAN ELECTRICIANS' HANDBOOK for additional data on molding wiring.

Why wires are permitted in wood moldings and are not, when installed in accordance with the other methods of wiring, allowed to touch wood is a question that is sometimes asked. The wires in a molding installation are installed in a specially prepared protecting raceway and should, under the conditions (dry places only) where molding wiring is permitted, provide adequate security to the conductors. On the other hand, wiring installed in accordance with the other methods is not permitted to touch wood because with these other methods the wires can be run in locations where the wood might become damp and result in grounds on the circuit and consequent fire hazard.

The use of wooden molding is being discontinued in spite of the fact that the Code permits its use under certain condi-

tions. Metal molding is safe and is being widely applied but in certain cities, in New York and St. Louis for example, the installation of wooden molding is prohibited by the local municipal rules.

26*l*. ¶*I*. WIRES—MOULDING. Must never be placed in either metal or wooden moulding in damp locations; must never be placed in either metal or wooden moulding in concealed locations or where the difference of potential between any two wires in the same system is over 300 volts. When the electrical construction is being carried out in metal moulding, permission will be given to extend these mouldings through walls and partitions if the moulding and capping are in continuous lengths where passing through the walls and partitions. Not more than four No. 14 B. & S. gage rubber covered wires, and no single circuit of more than 1,320 watts shall be used in metal moulding.

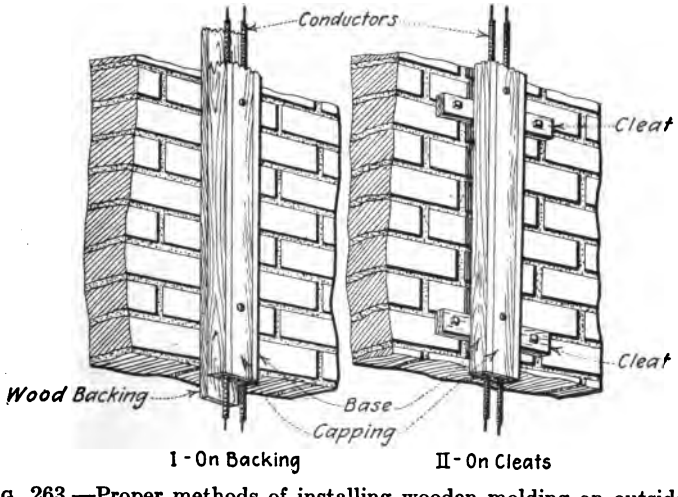


FIG. 263.—Proper methods of installing wooden molding on outside of brick or stone walls.

Molding wiring should never be installed in damp places. This applies to wiring in metal as well as to that in wooden molding. The conductors are close together and furthermore the structure of the molding is such that moisture can readily enter it. Hence if it is used in a damp location, low resistance to ground and between conductors will result and trouble will, probably, ultimately occur. If the wood molding becomes damp, it may, at a weak point in the insulation

on the conductors, constitute a high-resistance conducting path and carry current until it chars. Then it will ignite readily and may start a fire.

Outside brick and masonry walls are considered as damp places. Therefore, either metal or wood molding when it is carried along such walls should be separated therefrom in accordance with methods similar to one of those suggested in Fig. 263. The backing or cleats on which the molding is supported should be thoroughly painted or impregnated to prevent its absorbing moisture.

Where wood molding passes through floors it may be arranged somewhat as suggested in Fig. 264. A floor block at least 2 in. high should be fastened to the floor and holes bored through this block to accommodate the porcelain tube bushings for the conductors. The function of a floor block is to raise the heads of the tubes high enough above the floor so that scrubbing water cannot enter them. The floor block and the lower end of the molding above it should be protected by wooden boxing, not shown in the illustration. Specially manufactured devices or "kick plates" (see AMERICAN ELECTRICIANS' HANDBOOK) can be procured to protect molding where it passes through a floor.

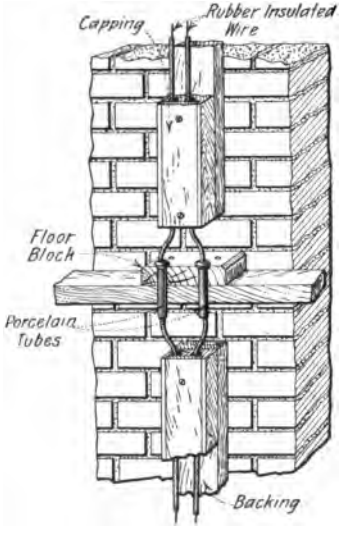


FIG. 264.—Molding wiring passing through floor.

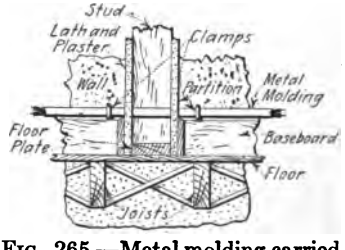


FIG. 265.—Metal molding carried through partition.

The method of carrying a metal molding run through a partition is shown in Fig. 265. The base and capping of the

molding must be continuous through the partition, that is, there must be no joints within the partition space.

Hardwood wooden molding only is accepted in certain cities (where the use of wooden molding is allowed) it being maintained that the soft wood or white wood molding is of sufficient strength to properly perform its function.

In supporting wood molding care must be taken not to cut away too much of the groove in the backing. The tendency is, particularly when the molding is being clamped to the supporting surface with toggle bolts, to cut large gaps in the tongue of the backing. This weakens the backing and may permit the electrical contact through the nut on the toggle bolt of the conductors of opposite polarity in the molding.

The places where molding should not be used (this applies to both wood and metal molding) are, in cellars, in damp places, out of doors, or in elevator shafts (*Rule* 16*g*, ¶*I*). In some cities, the use of molding is prohibited in churches and auditoriums. Wood molding should not be used in show windows, because of the liability in these locations of nails and tacks being driven through the capping and into contact with the conductors.

26*m*. ¶*I*. WIRES—MOULDING. Must for alternating current-systems if in metal moulding have the two or more wires of a circuit installed in the same moulding.

For alternating-current circuits in metal molding all of the wires of the circuit must be installed in the same molding because of the possible eddy-current and inductive-drop difficulties that may be encountered where one wire of such a circuit is installed in a molding. The reasons for this requirement are the same as those which dictate similar regulations for wiring in wrought-iron conduit and which are discussed under *Rule* 26*p*, ¶*I*.

26*m*. ¶*I*. NOTE. WIRES—MOULDING. It is suggested that this be done for direct current systems also, so that they may be changed to alternating systems at any time, induction troubles preventing such a change if the wires are in separate mouldings.

FOR CONDUIT WORK

The following rules concerning conduit work apply, in general, to both flexible and rigid metallic conduit. There are no rules

in the CODE applying only to flexible steel conduit. However, some of the rules for armored cable under *Rule* 27 may be taken as applying to flexible steel conduit.

The function of a conduit system is to provide a permanent raceway for the protection of electrical conductors which will permit the withdrawal and replacement of the conductors if such is desirable or necessary. Rigid conduit, which is specially treated steel pipe, and the pressed-steel outlet and terminal boxes are obviously well qualified to protect the conductors encased in them from mechanical injury. It will also prevent the spread of fire outside of the conduit system in case the insulation on the conductors within the system becomes ignited because of an accidental ground or short-circuit. A conduit system should of itself have relatively high electrical conductivity because under certain abnormal conditions (which are discussed later), the pipes and other metal of the installation may carry current. Hence a conduit system must have sufficient conductivity that it can carry such currents for the short periods that will ensue before the cut-out (fuse or circuit-breaker) protecting the circuit operates and discontinues the circuit. Normally, the conduit does not and should not carry current, but under abnormal conditions it *may* carry current and must be proportioned and assembled accordingly.

Rigid conduit provides the safest and best of all of the methods of wiring and should, in general, except under certain special conditions, be used in preference to any of the other methods. Its disadvantage is that it is the most expensive, with the possible exception of certain special forms of wiring.

26*n*. ¶*I*. WIRES—CONDUIT. Must have an *approved* rubber insulating covering, and within the conduit tubing must be without splices or taps. Must be double braided (Type Letters R. D.) for twin, twisted pair or multiple conductor cables and for all single conductors of No. 6 B. & S. gage and larger.

26*n*. ¶*II*. WIRES—CONDUIT. Slow burning insulation may, however, be used in permanently dry locations where excessive temperatures are present, provided special permission in writing be given in advance.

Rubber-insulated wire must be used in conduit except in hot, permanently dry locations. Obviously, the conductors

of opposite polarity within a conduit are very close together and the insulation resistance between them is determined almost solely by the quantity and quality of material (insulation) in which the copper wires are encased. It is evident then that only the very best and most effective materials should be used for insulating these conductors. Prior to the issuance of the 1915 CODE, double-braided, rubber-insulated conductors were required for conduit work. Experience has shown, however, that single-braid insulation is ample for this service for conductors smaller than No. 6 B. & S. or American wire gage. Now single-braid rubber insulation is approved for conductors smaller than No. 6, for knob-and-tube, molding, conduit and open work, rendering it unnecessary for the dealer to stock these wires with two kinds of insulations as was formerly required.

Splices or taps should never be made within the conduit tubing because a splice or a joint is of necessity weaker electrically than the unimpaired conductor. If splices were permitted within the conduit tube, the insulation strength of the system would be materially weakened. (Splices and taps should, as will be hereinafter shown, be made only in accessible outlet or junction boxes.) Furthermore, a splice is of necessity, if it is made in accordance with the CODE (*Rule* 16*c*, ¶*I*) of greater overall diameter than the conductor in which it is made. Therefore, if a splice is drawn into a conduit tube, there is danger of the insulation round the splice being disturbed and of the joint being injured mechanically.

26*o*. ¶*I*. WIRES—CONDUIT. Must not be drawn in until all mechanical work on the building has been, as far as possible, completed.

The conductors of a conduit system should not be drawn in until the mechanical work in the structure has been completed. This is necessary in order to prevent unauthorized workmen from damaging the insulation on the conductors or the conductors themselves, where they extend from the outlet boxes, and furthermore, to insure that the conductors can actually be removed and replaced after the building is finished. Frequently conduit in a building under construction

is battered and crushed after its installation, even when the building is nearly completed. If the conductors were already in such tubes they might be wedged, preventing withdrawal. Furthermore, if the wire is pulled into a conduit system before the runs are fully encased in floors and partitions the wireman may, if he experiences difficulty, open a conduit run at a running thread joint or at a coupling, to facilitate his work, and pull in wires both ways from a break thus made. Obviously, conductors installed by such methods may be impossible of removal.

26o. ¶*II.* WIRES—CONDUIT. Conductors in vertical conduit risers must be supported within the conduit system in accordance with the following table:

No. 14 to 0 inclusive every 100 feet.
No. 00 to 0000 inclusive every 80 feet.
Above 0000 to 350,000 C. M. inclusive every 60 feet.
Above 350,000 C. M. to 500,000 C. M. inclusive every 50 feet.
Above 500,000 C. M. to 750,000 C. M. inclusive every 40 feet.
Above 750,000 C. M. every 35 feet.

Conductors in vertical conduit risers should be supported to prevent excessive strains due to the weight of the conductors being imposed on the lugs and binding posts of the switches or cut-outs to which the conductors connect.

26o. ¶*III.* WIRES—CONDUIT. The following methods of supporting cables are recommended:

26o. ¶*III.* 1. WIRES—CONDUIT. *Approved* clamping devices constructed of or employing insulating wedges inserted in the ends of conduits.

26o. ¶*III.* 2. WIRES—CONDUIT. Junction boxes may be inserted in the conduit system at the required intervals, in which insulating supports of *approved* type must be installed and secured in a satisfactory manner so as to withstand the weight of the conductors attached thereto, the boxes to be provided with proper covers.

26o. ¶*III.* 3. WIRES—CONDUIT. Cables may be supported in *approved* junction boxes on two or more insulating supports so placed that the conductors will be deflected at an angle of not less than 90 degrees, and carried a distance of not less than twice the diameter of the cable from its vertical position. Cables so suspended may be additionally secured to these insulators by tie wires.

26o. ¶*IV.* WIRES—CONDUITS. Other methods may be used if specially approved.

There are three approved methods of supporting vertical conductors. The first method is illustrated in Fig. 266, *III*, where an insulated, wedge-split bushing is used in supporting

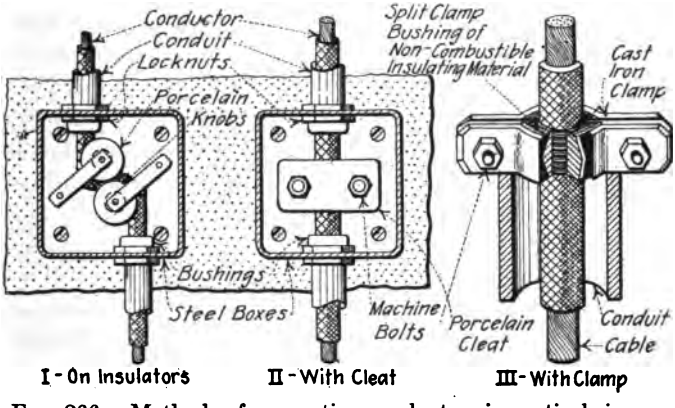


FIG. 266.—Methods of supporting conductors in vertical risers.

the conductor. The bushing shown in the illustration is clamped in a yoke which rests on the top of the conduit but similar non-combustible insulating bushings (Fig. 267) which

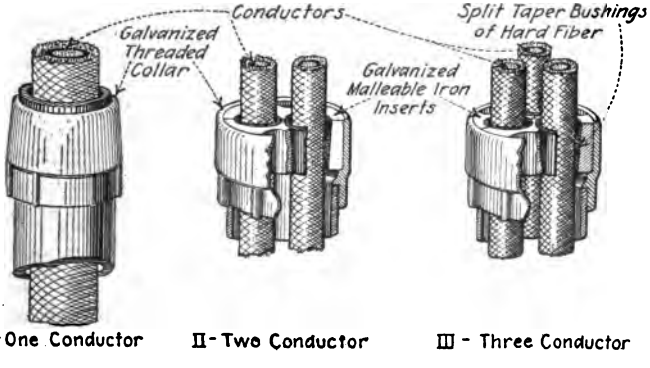


FIG. 267.—A split-wedge cable support. (Russel & Stoll, New York City.)

require no yoke are manufactured for clamping one, two and three wires. These bushings are arranged to wedge down into the conduit bushings which are screwed on the upper ends of

runs of tubing. Fig. 266, *II*, and Fig. 268 show methods of supporting vertical conductors with clamps mounted in junction boxes. At *II* the insulating clamp consists merely of a two-piece porcelain cleat attached to the back of the junction box with a couple of bolts. The insulation is not removed from the conductor; hence the clamp exerts its action by biting into the insulating material.

In Fig. 268, a method used for heavy conductors, the clamps are of metal and are soldered directly to and clamped over the conductors to be supported. As shown, the braid and rubber

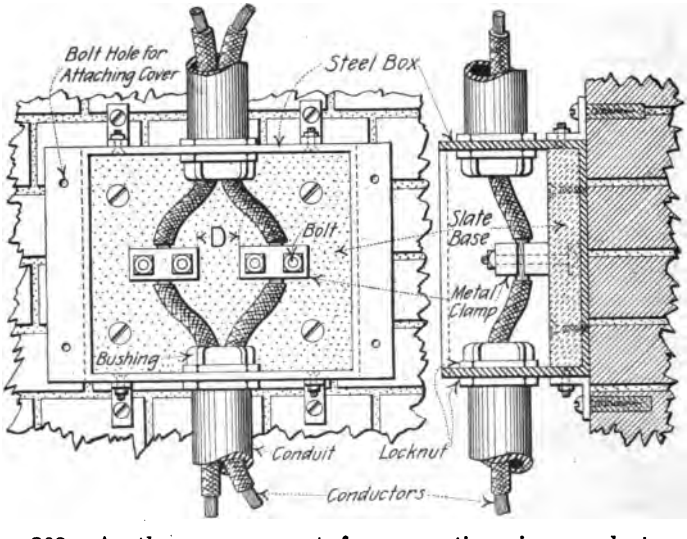


FIG. 268.—Another arrangement for supporting riser conductors in conduit.

must be removed from the conductor before the clamp is applied. Insulation is provided by the slate slab fastened in the back of the junction box. The minimum distance, *D*, between the two bare metal clamps of opposite polarity is determined by the voltage between the conductors and should be in accordance with the requirements of *Rule* 69*b* which specifies the allowable spacings between live metal parts on panel boards. Fig. 266, *I*, shows a method of supporting a

conductor by deflecting it at an angle of not less than 90 deg. Tie-wires may be used with this arrangement but are frequently unnecessary.

Where supporting a number of conductors in a vertical run the usual practice is to arrange steel junction boxes at intervals and to install in each of these boxes a sufficient number of supports, of one of the types shown, for all of the conductors in the run. That is, it is unnecessary to use, as the illustrations indicate, a separate junction box for each conduit in the run. One large junction box inserted in the run can be arranged to enclose all of the supports for all of the conductors in the run.

Strain insulators and turn buckles are often used at the upper end of a vertical run to assume the vertical stress, but in addition the supports as described in the preceding paragraphs should also be used.

26*p*. ¶*I*. WIRES—CONDUIT. Must, for alternating systems, have the two or more wires of a circuit drawn in the same conduit.

Where alternating-current conductors are in conduit all of the wires of a circuit—two wires for a single-phase circuit or three wires for a three-phase circuit—must be in the same tube. Where a single wire carrying alternating current is by itself in a conduit, eddy currents are induced in the tube which may, under certain conditions, heat it to a dangerous temperature. Furthermore, where a single alternating-current conductor is in an iron tube, the voltage drop in the circuit is materially increased because of the inductive counter e.m.f. due to the presence of the iron around the conductor. Where all of the conductors of the circuit are in the same tube the tendency toward the production of eddy currents and toward the development of excessive inductive drops is practically eliminated.

26*p*. ¶*I*. NOTE. WIRES—CONDUIT. It is suggested that this be done for direct current systems also, so that they may be changed to alternating systems at any time, induction troubles preventing such a change if the wires are in separate conduits.

All of the conductors of a direct-current system need not be in the same tube because with direct currents the eddy

currents and inductive effects above referred to do not exist. However, the liability of a change-over from direct to alternating current always exists. There have been cases where in changing over direct-current systems, that were wired one conductor to a tube, to alternating-current systems, it was necessary to tear out and replace the whole installation because of the dangerous heating that developed in the ducts containing one wire when an attempt was made to use them in alternating-current service.

26*p*. ¶*II*. WIRES—CONDUIT. Except in the case of stage pocket and border circuits the same conduit must not contain more than four two-wire, or three three-wire circuits of the same system, except by special permission, and must never contain circuits of different systems.

The number of conductors in any one conduit should be minimized in order to reduce the amount of combustible (insulating) material in the conduit, and also because where a considerable number of wires is placed in one duct they may wedge, rendering withdrawal difficult or impossible. See discussion under *Rules* 38, and 39 for information relative to stage border light and pocket wiring.

FOR CONCEALED "KNOB-AND-TUBE" WORK

Knob-and-tube wiring was formerly used in practically all frame buildings and still finds wide application. Its installation is, however, now prohibited in certain cities—Chicago, Milwaukee and Denver, for instance—where, by municipal ordinance, conduit or armored-cable wiring only is permitted for concealed work. Knob-and-tube is the cheapest of all of the methods of concealed wiring and can, obviously, be used only in frame buildings or in brick or masonry buildings with wooden floors and partitions. See the author's AMERICAN ELECTRICIANS' HANDBOOK for additional information relative to knob-and-tube wiring.

The disadvantageous features of knob-and-tube wiring are: (1) The conductors are unprotected from mechanical injury. (2) A fire originating in rubber insulation on one of the conductors will readily follow along that conductor and may ignite adjacent timbers. (3) Even, if when the installa-

tion is made, all of the conductors are thoroughly insulated in accordance with prescribed practice, there is no assurance that they will remain so. The warping and shrinkage of timbers, the settling of the building and the breakage of the brittle porcelain knobs and tubes may permit the conductors to contact with damp wood or grounded pipes. (4) The porcelain-tube bushings used for protecting the conductors through joists may, and often do, back out of the timbers and permit the conductor to contact with them. (5) Grounded metal work, such as pipes, steel beams and girders, are liable to be placed in contact with the conductors after they are installed, but before the building is finished. Sometimes these interfering members may be placed after the building is finished. (6) Building tradesmen, other than wiremen, may, after the wireman has left the job and prior to plastering, place members in contact with the conductors.

26*q*. ¶*I*. WIRES—CONCEALED "KNOB AND TUBE." Must have an *approved* rubber insulating covering (Type Letter R. S. for wires smaller than No. 6 B. & S. gage and Type Letter R. D. for wires No. 6 and larger).

Knob-and-tube-wiring conductors should have rubber insulation. It is apparent from a consideration of the above outlined disadvantageous features of the method that only the very best insulation should be used because of the possibility of the conductors touching wood or metal work. Rubber is the best insulation for conductors that is commercially available.

26*r*. ¶*I*. WIRES—CONCEALED "KNOB-AND-TUBE." Must be rigidly supported on non-combustible, non-absorptive insulators which separate the wire at least one inch from the surface wired over. Should preferably be run singly on separate timbers, or studding, and must be kept at least five inches apart.

Knobs giving a 1-in. separation from the surface should be used in knob-and-tube work (Fig. 269). Porcelain cleats do not ordinarily provide this separation; hence they should not be applied.

The conductors should always be run on separate timbers where possible as shown in Figs. 269, 270, and 271, *I*, to reduce

the liability of their touching one another. Even where the 5-in. separation, which is prescribed for knob-and-tube work, can be maintained between the conductors it is better to support them on separate timbers where feasible.

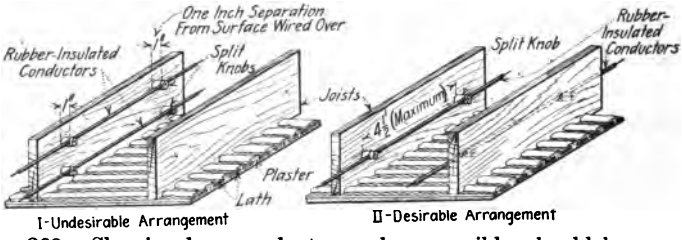


FIG. 269.—Showing how conductors, where possible, should be run on separate timbers.

The details of an entrance into a frame building in a knob-and-tube installation are shown in Fig. 272. The entrance

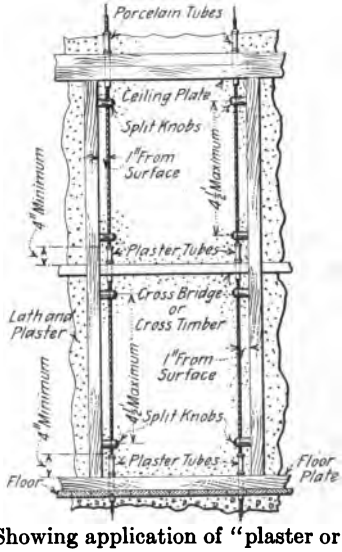


FIG. 270.—Showing application of "plaster or mud tubes."

switch is located in the basement and the conductors are carried thereto from the entrance outlet down in the outside wall space between studs.

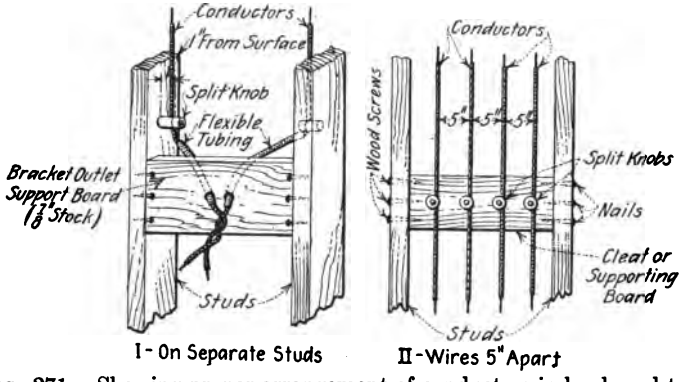


FIG. 271.—Showing proper arrangement of conductors in knob-and-tube installation.

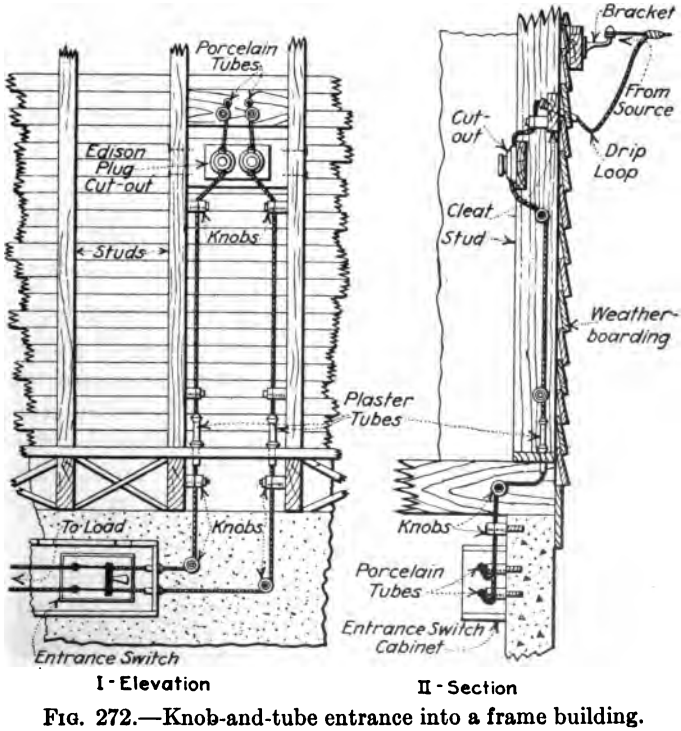


FIG. 272.—Knob-and-tube entrance into a frame building.

26r. ¶*II.* WIRES—CONCEALED "KNOB-AND-TUBE." Must be separated from contact with the walls, floor timbers and partitions through which they may pass by non-combustible, non-absorptive, insulating tubes, such as glass or porcelain. Wires passing through cross timbers in plastered partitions must be protected by an additional tube extending at least four inches above the timber.

Where the conductors pass through timbers the holes should be bushed with porcelain tubes as shown in Fig. 270. Joists should be similarly bushed. A damp timber may be a reasonably good conductor, hence this provision.

"Plaster tubes" should be used where the conductors pass through horizontal timbers. These are sometimes called '*mud tubes.*" Their function is to prevent the plaster droppings from contacting with the conductor. Dry plaster is a fairly good insulator, but wet plaster is a good conductor and, furthermore, may have an injurious chemical effect on the wire and its insulation. "Plaster" or "mud" tubes are not made of plaster or clay but are porcelain tubes of identically the same dimensions and composition as the other tubes used for bushing the conductors through the timbers.

26r. ¶*III.* WIRES—CONCEALED "KNOB-AND-TUBE." Rigid supporting requires, under ordinary conditions, where wiring along flat surfaces, supports at least every four and one-half feet. If the wires are liable to be disturbed the distance between supports must be shortened.

The minimum permissible distance between supports is 4 ft. 6 in. as indicated in Fig. 270. That is, a knob should be placed at least every 4 ft. 6 in. along every conductor unless tubes, which in themselves constitute supports, are interposed between. Frequently, particularly in unfinished basements and in other places where the wires are liable to mechanical interferences, it is well to locate the knobs 2 ft. 6 in. or 3 ft. apart.

26r. ¶*IV.* WIRES—CONCEALED "KNOB-AND-TUBE." At distributing centers, outlets or switches where space is limited, and the five-inch separation cannot be maintained, each wire must be separately encased in a continuous length of *approved* flexible tubing.

Where the wires cannot be separated, 5-in. flexible tubing should be slipped over the conductors for additional protection,

as shown in Figs. 273, 274 and in following illustrations. See discussion under *Rule* 26*u*, ¶*I*.

Use plenty of knobs and tubes and flexible tubing to prevent the possibility of a non-insulated member contacting with the

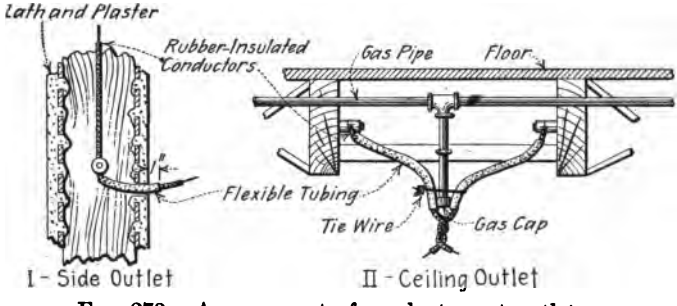


FIG. 273.—Arrangement of conductors at outlets.

conductors. Where there is any doubt as to the possibility of a future accidental contact, place another knob and tube or use more flexible tubing, as the case may require. Fig. 275 shows an example of a complicated knob-and-tube installation.

26*s*. ¶*I*. WIRES—CONCEALED "KNOB-AND-TUBE." When in a concealed knob and tube system, it is impracticable to place the whole of a circuit on non-combustible supports of glass or porcelain, that portion of the circuit which cannot be so supported must be installed with *approved* metal conduit, or *approved* armored cable, except that if the difference of potential between the wires is not over 300 volts, and if the wires are not exposed to moisture, they may be fished if separately encased in *approved* flexible tubing, extending in continuous lengths from porcelain support to porcelain support, from porcelain support to outlet, or from outlet to outlet.

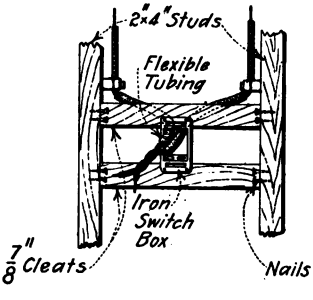


FIG. 274.—Flexible-tubing-encased conductors entering a metal outlet box.

Where conductors must be installed on or in brick or masonry walls, steel conduit is used as shown in Fig. 276.

Such walls, particularly outside walls, may be "damp places." They are so considered; hence a flexible-tubing-encased conductor should not be imbedded in them or should it be placed where it will be imbedded in plaster. The illustration shows how the conduit is applied in combination with knob-and-tube

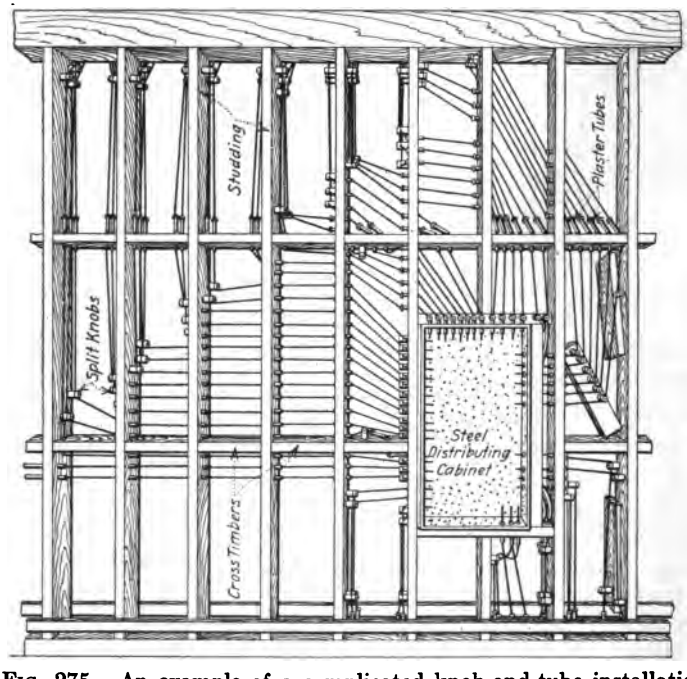


FIG. 275.—An example of a complicated knob-and-tube installation. Where, as in the example shown in this picture, there are a large number of knob-and-tube conductors concentrated in one location it does not always appear to be feasable to adhere strictly to all of the CODE requirements for knob-and-tube wiring. As a rule, it is not good practice to so design any knob-and-tube installation, that as many circuits as shown above will originate from one distribution center or panel box.

wiring. A conduit run must always terminate in an accessible outlet box or fitting, hence an accessible outlet box must be located where knob-and-tube wiring joins conduit wiring. Usually the outlet box, in which the junction is made, is located at a fixture or bracket outlet as shown in Fig. 276, so that the fixture canopy covers it after the installation has been

completed. Either rigid conduit or flexible conduit may be installed in the brick walls, masonry or plaster. The installation must be complete (and in the case of flexible conduit the walls should be dry) before the wire is pulled into the conduit. If flexible conduit is used, that of the ordinary type is usually accepted by wiring inspectors, but if the walls or location will always be damp, flexible conduit having a lead gasket wound within it (*BXL*) or flexible conduit otherwise manufactured in

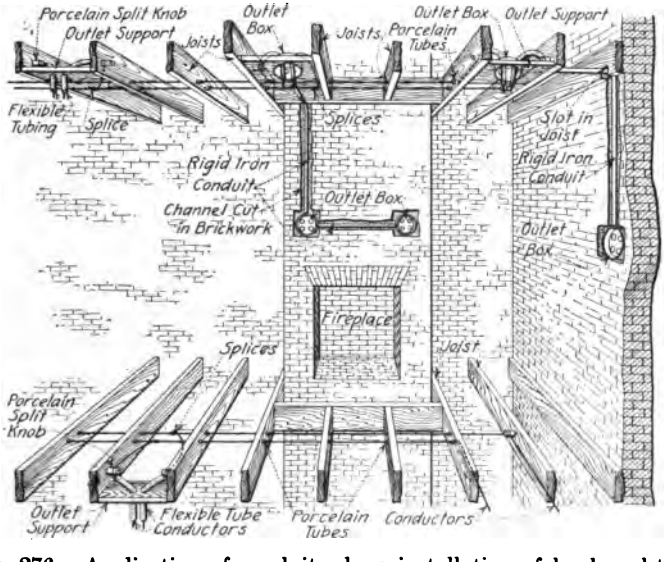


FIG. 276.—Application of conduit where installation of knob-and-tube work is impracticable.

such a way as to be watertight is ordinarily required. Leaded armored cable may be used instead of conduit.

26*t*. ¶*I*. WIRES—CONCEALED "KNOB-AND-TUBE." When using either conduit or armored cable in mixed concealed knob and tube work, the requirements for conduit work or armored cable work must be complied with as the case may be.

When installing short conduit runs in combination with a knob-and-tube system the essential rules covering the installation of conduit should be followed, that is, the conduit

should be continuous from outlet to outlet and must be fitted at all outlets with suitable steel outlet boxes, bushings and locknuts. The other rules relating to conduit installations also apply, in general, with the exception that it is not usually considered necessary to ground the short conduit runs. The conduits in these cases are frequently considered as coming under the head of protective runs and are, therefore, subject to the specifications of *Rule* 26*e*, ¶*III*, wherein it is specified that conduit used for side-wall protection need not be grounded. Some inspectors do not require the grounding of a protective conduit run unless the run is of excessive length. Ordinarily it is considered unnecessary to ground a run unless it has a length greater than 10 or 12 ft.

26*u*. ¶*I*. WIRES—CONCEALED "KNOB-AND-TUBE." Must at all outlets, except where conduit is used, be protected by *approved* flexible tubing, extending in continuous lengths from the last porcelain support to at least one inch beyond the outlet. In the case of combination gas and electric outlets the tubes on the wires must extend at least flush with the outlet ends of gas caps, and if box or plate is used, gas pipes must be securely fastened into the outlet box or plate to secure good electrical connection.

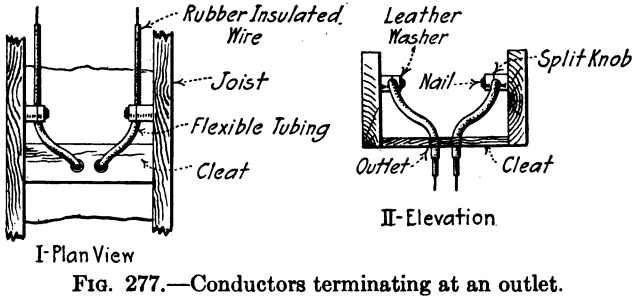


FIG. 277.—Conductors terminating at an outlet.

Conductors should be encased in flexible tubing at all outlets (see Figs. 271, *I*, 273, 274, 277, 278 and 279 and other illustrations). This is, in a sense, merely a repetition of the requirement, previously cited, that all conductors should, in general, be encased in tubing if the distance between them is less than 5 in. The tubing should extend past the gas-

pipe cap at gas-and-electric-fixture outlets to prevent the unprotected conductor from contacting with the gas pipe.

Also at a combination-fixture outlet, the pieces of tubing may be bound to the gas pipe with an iron or copper tie-wire as shown in Fig. 273, *II*, to hold them close together to insure that

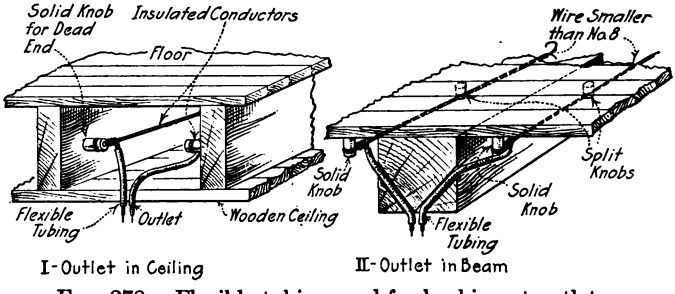


FIG. 278.—Flexible tubing used for bushing at outlets.

the fixture canopy, after it is installed, will cover the wire ends. The tie wire also prevents the tubing from slipping down. In applying the tie-wire care should be taken not to draw it so tight as to cut the tubing. The tubing should extend at least 1 in. beyond the wall or ceiling surface as shown in Fig. 271, *I*.

Only continuous lengths of tubing should be used for wire protection at outlets. It is inadvisable and poor practice to slip several short lengths of tubing over the conductor because they are liable to separate, leaving the wire unprotected. The conductors should, prior to the completion of the job, be twisted together outside of the outlet as suggested in the illustrations to prevent the tubing from slipping off.

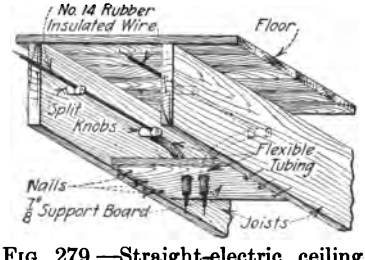


FIG. 279.—Straight-electric ceiling outlet (knob-and-tube method).

Every wire should be fastened by a knob at every outlet. It is not sufficient for it to merely pass through a tube near an outlet. This is particularly true in the case of outlets at the ends of long runs. Unless the knob is so located as to hold the

wire at the end of the run, the wire is liable to sag back and touch wood or metal. Fig. 278 illustrates this point.

26u. ¶II. WIRES—CONCEALED "KNOB-AND-TUBE." When the surface at any outlet is broken, it must be repaired so as to leave no holes or open spaces at such outlet.

Holes around outlets should be closed with plaster because a draft may draw a flame from burning conductors or some other source into the partition space. This requirement is of particular importance in wiring finished frame buildings.

26u. ¶II. NOTE. WIRES—CONCEALED "KNOB-AND-TUBE." It is suggested that *approved* outlet boxes or plates be installed at all outlets in concealed "knob and tube" work, the wires to be protected by *approved* flexible tubing, extending in continuous lengths from the last porcelain support into the box.

27. ARMORED CABLES.

(*See also No.* 26 *s. For construction of Armored Cables see No.* 57)

Armored cables are made by serving sheet-steel strips spirally around rubber-insulated copper conductors. The sheet-steel sheath affords a reasonably flexible protective cas-

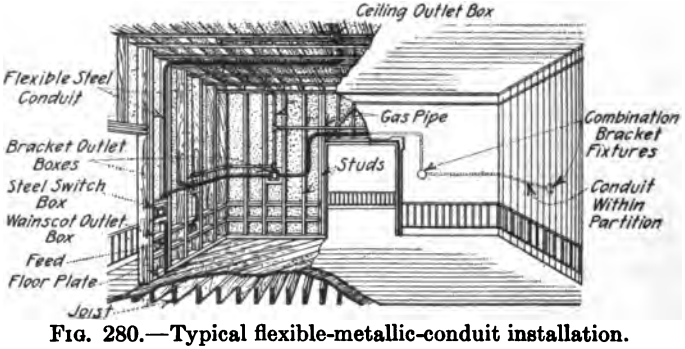


FIG. 280.—Typical flexible-metallic-conduit installation.

ing. Armored cable is then, merely flexible conduit with the two or three conductors, as the case may be, already installed within it. However, the casing is wrapped tightly around the conductors so they cannot be withdrawn. The sheath is constructed in practically the same manner as is flexible conduit. Numerous methods have been adopted by the different manufacturers for making armored cable and for

locking together the edges of the strip spirals. It is frequently used in finished-building wiring but is somewhat more expensive than conduit wiring, hence is applied only in cases where conduit cannot be conveniently used. It has the advantage that it can be fished with impunity through any place within a building. Fig. 280 shows a typical flexible or armored conduit installation. In general, the same installation requirements apply for armored cable as for rigid and flexible-steel conduit. See the author's AMERICAN ELECTRICIANS' HANDBOOK for additional information relating to the installation of armored cable and conduits.

There are two kinds of armored cable: moistureproof and non-moistureproof. The construction of cables of the non-moistureproof type is such that moisture may and sometimes does enter the protective casing through the joints between the spiral strips. In the non-moistureproof types, the entrance of moisture is prevented either by a spiral lead gasket or by the inherent construction of the cable sheath. Cable of the type using the lead gasket is sometimes called leaded armored cable. Moistureproof cable should be used in places that are permanently damp.

27a. ¶I. ARMORED CABLE. Must be continuous from outlet to outlet or to junction boxes or cabinets, and the armor of the cable must properly enter and be secured to all fittings, and the entire system must be mechanically secured in position.

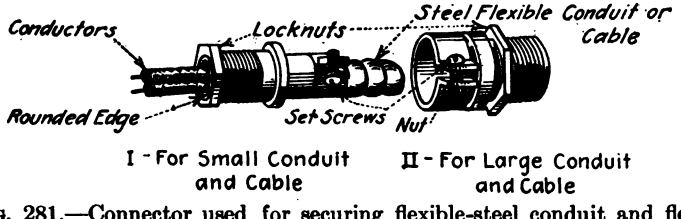


FIG. 281.—Connector used for securing flexible-steel conduit and flexible-steel armored cable in wooden-panel boxes.

The methods of securing armored cables in outlet boxes are illustrated in Figs. 281 and 282. A special fitting or connector (Fig. 281) must be used at the end of each cable run to provide a means of attaching the cable in the outlet box and to

provide at the end of the sheath a rounded edge on which the conductors may bear. The same terminal connectors are used with armored cable as with flexible-steel conduit.

Couplings cannot be used with armored cable. While couplings or "straight" connectors may be used for joining together lengths of flexible-steel conduit, they cannot be used with armored cable inasmuch as it must be continuous from outlet to outlet without joints or splices. Fig. 283 shows the application of couplings for joining rigid and flexible conduit.

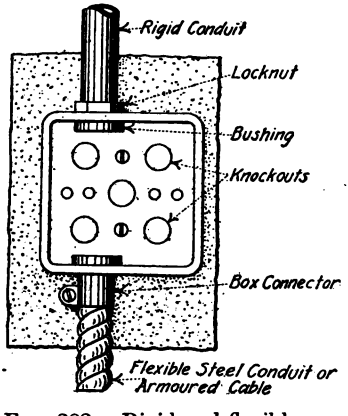


FIG. 282.—Rigid and flexible conduit fastened in outlet box.

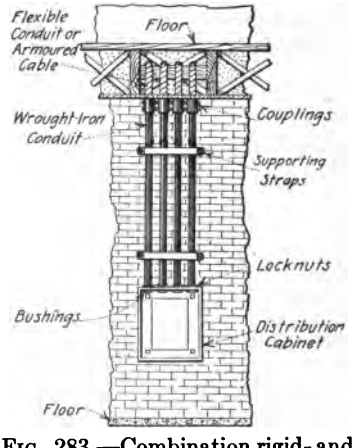


FIG. 283.—Combination rigid- and flexible-conduit wiring.

Couplings should not be applied in this manner in armored-cable runs.

27*a*. ¶*II*. ARMORED CABLES. In case of service connections and main runs, this involves running such armored cable continuously into a main cut-out cabinet or gutter surrounding the panel board, as the case may be.

27*b*. ¶*I*. ARMORED CABLES. Must be equipped at every outlet with an *approved* outlet box or plate, as required in conduit work.

27*b*. ¶*II*. ARMORED CABLES. Outlet plates must not be used where it is practicable to install outlet boxes.

Outlet plates, Fig. 284, may be used with armored cable or with flexible conduit. In the plate illustrated, which is for a combination gas-and-electric outlet, wedge-bushings are

provided for clamping the sheath of the cable or the conduit in the fitting and for providing a rounded edge upon which the conductor may bear. The hole in the center of the plate is for the admission of the gas pipe and a set-screw is provided for securing the plate to the pipe and for grounding it thereon.

27b. ¶*III*. ARMORED CABLES. For concealed work in walls and ceilings composed of plaster on wooden joist or stud construction, outlet boxes or plates and also cut-out cabinets must be so installed that the front edge will not be more than one-fourth inch back of the finished surface of the plaster, and if this surface is broken or incomplete it shall be repaired so that it will not show any gaps or open spaces around the edges of the outlet box or plate or of the cut-out cabinet. On wooden walls or ceilings, outlet boxes or plates and cut-out cabinets must be so installed that the front edge will either be flush with the finished surface or project therefrom. This will not apply to concealed work in walls or ceilings composed of concrete, tile or other non-combustible material.

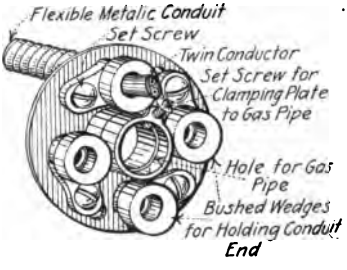


FIG. 284.—Cast-iron outlet plate for flexible-steel conduit or flexible-steel armored cable.

No gaps or open spaces should be left around outlet boxes or plates set in walls because of the possibility of flames originating in the outlet boxes being drawn to within the wall or partition.

27b. ¶*IV*. ARMORED CABLES. In buildings already constructed where the conditions are such that neither outlet box nor plate can be installed, these appliances may be omitted by special permission, provided the armored cable is firmly and rigidly secured in place.

27c. ¶*I*. ARMORED CABLES. Must have the metal armor of cables permanently and effectually grounded to water piping, gas piping or other suitable grounds, provided that when connections are made to gas piping, they must be on the street side of the meter. If the armored cable system consists of several separate sections, the sections must be bonded to each other, and the system grounded, or each section may be separately grounded, as required above.

Armored-cable sheaths must be grounded for the same reason that dictates the grounding of conduit systems (*Rule* 28*f*, ¶*I*). Ground clamps are used for the purpose and they are

installed in substantially the same manner as are those used for conduit. See the Author's AMERICAN ELECTRICANS' HANDBOOK for additional information.

27*c*. ¶*II*. ARMORED CABLES. The armor of cables and gas pipes must be securely fastened in outlet boxes, junction boxes and cabinets, so as to secure good electrical connection.

27*c*. ¶*III*. ARMORED CABLES. If armor of cables and metal of couplings, outlet boxes, junction boxes, cabinets or fittings having protective coating of non-conducting material, such as enamel are used, such coating must be thoroughly removed from the threads of both couplings and the armor of cables, and from surfaces of the boxes, cabinets and fittings where the armor of cables or ground clamp is secured in order to obtain the requisite good connection. Grounded pipes must be cleaned of rust, scale, etc., at place of attachment of ground clamp.

27*c*. ¶*IV*. ARMORED CABLES. Connections to grounded pipes and to armor of cables must be exposed to view or accessible, and must be made by means of *approved* ground clamps.

27*c*. ¶*V*. ARMORED CABLES. Ground wires must be of copper, at least No. 10 B. & S. gage (where largest wire contained in cable is not greater than No. 0. B. & S. gage), and need not be greater than No. 4 B. & S. gage (where the largest wire contained in cable is greater than No. 0 B. & S. gage). They shall be protected from mechanical injury.

27*c*. ¶*V*. NOTE. ARMORED CABLES. The ground for the armored cable system is not to be considered as a ground for a secondary system (see No. 15).

Armored-cable sheaths and the metal boxes in which they terminate should form an electrically continuous system which should be grounded. The reasons for these requirements are the same that dictate similar requirements for rigid and flexible conduit and which are discussed under *Rules* 28*b*, ¶*I* and 28*f*, ¶*II*.

27*d*. ¶*I*. ARMORED CABLES. When installed in so-called fireproof buildings in course of construction or afterwards if exposed to moisture, or where it is exposed to the weather, or in damp places, such as breweries, stables, etc., the cable must have a lead covering placed between the outer braid of the conductors and the steel armor.

27*d*. ¶*II*. ARMORED CABLES. The lead covering is not to be required when the cable is run against brick walls or laid in ordinary plaster walls unless same are continuously damp.

Flexible-steel-armored cable installed in permanently damp places should have a lead protective covering interposed

between the rubber insulation on the wire and the steel protective sheath. Cable of this construction is known as leaded cable. In some localities armored cable without the additional lead sheath is not permitted for installation in fireproof buildings in course of construction because these are considered damp places due to the fact that the conductors will be exposed to the weather and moisture. The leaded covering is not ordinarily required in brick or masonry inside walls that will, after the building is finished, be dry. The lead covering is frequently required for cables installed in outside walls or when the walls will be moist permanently.

27*e*. ¶*I*. ARMORED CABLES. Where entering junction boxes, and at all other outlets, etc., must be provided with *approved* terminal fittings which will protect the insulation of the conductors from abrasions, unless such junction or outlet boxes are specially designed and approved for use with the cable.

Terminal fittings at outlet boxes, Figs. 281 and 282, take the place of the locknuts and bushings used with rigid conduit and perform two functions. They hold the end of the armored cable or flexible-steel conduit in the box and also provide bushing, protecting the conductors from abrasion where they emerge from the spiral-steel-strip sheath.

27*f*. ¶*I*. ARMORED CABLES. Junction boxes must always be installed in such a manner as to be accessible.

27*g*. ¶*I*. ARMORED CABLES. For alternating current systems must have the two or more conductors of the circuit enclosed in one metal armor.

27*h*. ¶*I*. ARMORED CABLES. All bends must be so made that the armor of the cable will not be injured. The radius of the curve of the inner edge of any bend not to be less than 1½ inches.

Armored cable and flexible conduit must not be bent to too short a radius because, if it is, the sheath is liable to be opened at the joints and the conductors may contact with the deformed inner layer of the sheet-metal sheath.

Armored cable in joists should always be so located that flooring nails will not enter it. This applies also to flexible-steel conduit because it is possible to drive a nail through the sheaths of either. Hence, where carried through joists, the

holes through which they pass should be located far enough from the tops of the joists that the nails driven to secure the floor or for other purposes will not penetrate them. They should be carried through holes near the middle of the joists rather than through slots in the top of the joists. In New York City slots for conduit in the tops of joists are not permitted. There the conduit or armored cable must be carried in holes bored through the joists about midway between the upper and lower edges.

28. INTERIOR CONDUITS.

(*See also No.* 26 *n to p. For construction of Conduit see No.* 58, *and for construction of Outlet Junction and Flush Switch Boxes see No.* 59.)

28*a*. ¶*I*. INTERIOR CONDUITS. No conduit smaller than one-half inch electrical trade size shall be used.

Conduit Smaller Than ½-in. Nominal Diameter should not be Used.—No. 14 (*Rule* 16*a*) is the smallest size conductor permitted for wiring except in certain special cases. Experience has shown that pipe of ½-in. nominal diameter is the smallest that will permit the ready insertion and withdrawal of two or three No. 14 rubber-insulated conductors.

28*b*. ¶*I*. INTERIOR CONDUITS. Must be continuous from outlet to outlet or to junction boxes or cabinets, and the conduit must properly enter, and be secured to all fittings and the entire system must be mechanically secured in position.

A conduit system must be continuous from outlet to outlet for two reasons: *First,* to insure that the entire raceway or tunnel in which the wires are carried will have a strong metal casing which will protect the conductors against mechanical injury and also localize a fire within the conduit system if one should start. *Second,* so that it will be certain that the conductors can be drawn into the conduit system and withdrawn from it at any time without damage or abrasion.

Every run of duct must terminate in an accessible steel outlet box in order to fulfill the requirements indicated above. Such an outlet box may be either a steel distribution cabinet, a steel switch box, a steel junction box or a fixture outlet box. Since the conductors must be without splices or taps in the

conduit, all splices or taps must be made in these steel outlet boxes.

Loop routing of wiring is necessary in concealed conduit installations to satisfy the requirements that all splices be in accessible outlet boxes. In knob-and-tube or in open wiring,

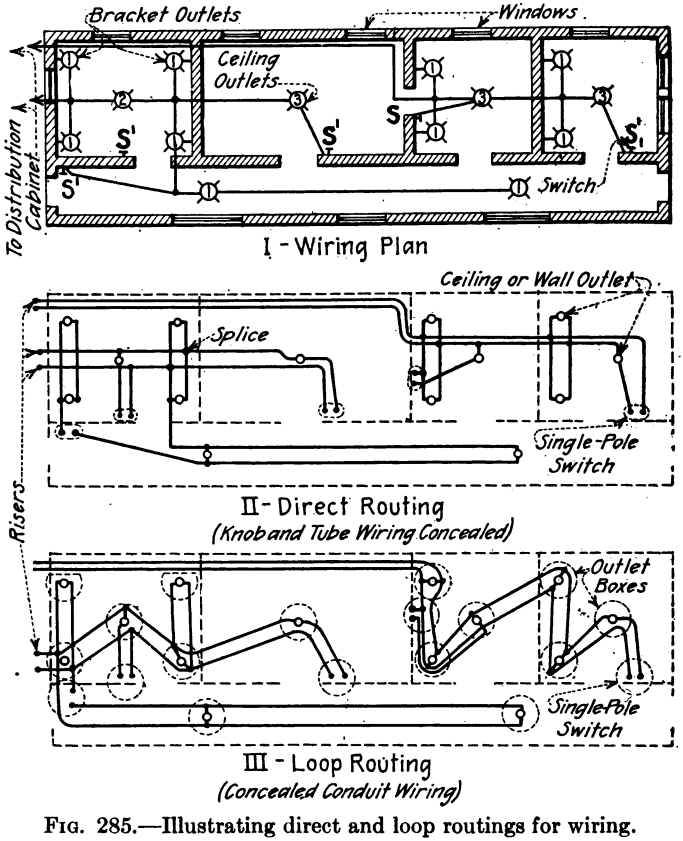


FIG. 285.—Illustrating direct and loop routings for wiring.

the conductors can ordinarily be laid out in accordance with a "direct routing" as suggested in Figs. 285, *II* and 286, *I*. This is permissible, since in wiring in accordance with these methods, the splices or joints may be made at any convenient point. Figs. 285, *III*, and 286, *II*, show how in conduit work

it is necessary to "loop" from outlet to outlet. It is usually cheaper to loop between outlets than it would be to insert additional junction boxes in which splices could be made whereby the looping could be eliminated. However, this is

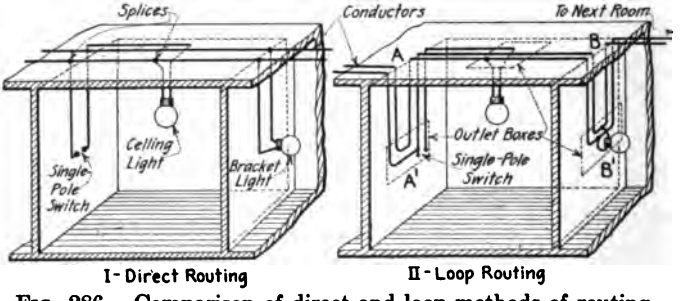


FIG. 286.—Comparison of direct and loop methods of routing.

not always the case. For example, it might be more economical in the case shown 286, in *II*, to install junction boxes near the ceiling, accessible from the room at points *A* and *B*, than to loop down as shown. If the junction boxes were installed, only one run of conduit would be required between *A* and *A'* and *B* and *B'* whereas with the loop routing, illustrated two conduit runs are necessary between *A* and *A'* and *B* and *B'*.

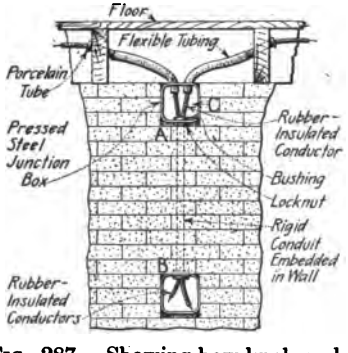


FIG. 287.—Showing how knob-and-tube wiring joins conduit wiring.

Conduit runs must extend into steel boxes—it is not sufficient that they extend merely up to the boxes. For example, in Fig. 287 it would not be permissible for the conduit length *AB* to extend from *B* to point *A* just outside of box *C*. The conduit must enter every box. If it does not enter, insertion and withdrawal of conductors will be difficult or impossible. Fig. 287 shows also how knob-and-tube wiring may join conduit wiring. Flexible tubing must encase the knob-and-tube con-

ductors from the last point of support and extend into the conduit outlet box to prevent the edges of the knockout holes from abrading the insulation on the wires.

The components of a conduit system should be secured mechanically in position, that is, the tubing, outlet and junc-

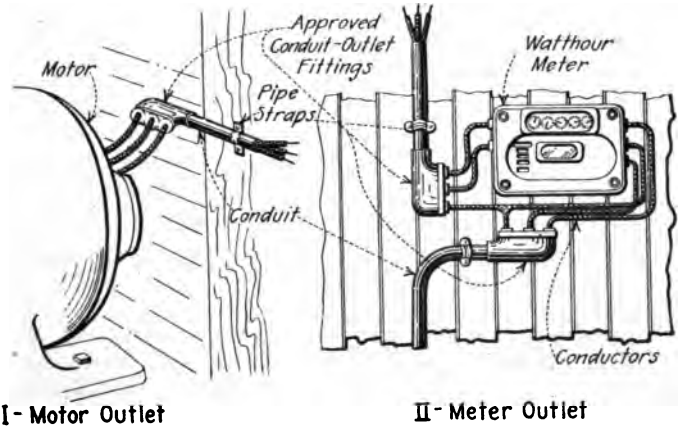


FIG. 288.—Showing application of approved outlet fittings.

tion boxes, must be supported rigidly. Pipe straps, held with nails or screws, may, as shown in Fig. 288, be used for supporting exposed conduit runs or concealed conduit runs in frame structures. Locknuts and bushings secure the conduit lengths

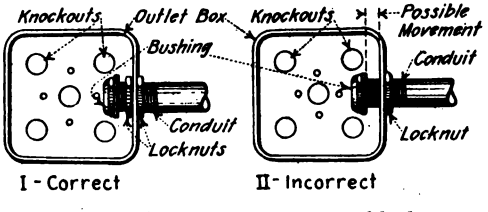


FIG. 289.—Correct arrangement of locknuts.

in the outlet boxes as shown in Figs. 268 and 289. In fireproof buildings, the conduit runs are imbedded in the walls and partitions and are thereby rigidly supported, as are the outlet boxes. In frame structures, the outlet boxes are held

with nails or screws driven through holes provided for their reception into wooden supporting strips.

In placing locknuts on conduit ends, two should be used at the end of each run as shown in Fig. 289, *I*. If only one is used there is usually a possibility of the end of the tube shifting back and forth in the knockout hole as shown at *II* because ordinarily the bushing itself does not clamp down against the box side. Where vibration is present or where conditions are such that the shifting of the conduit is aggravated, the conductors carried within the duct may have their insulation abraded or they may be broken.

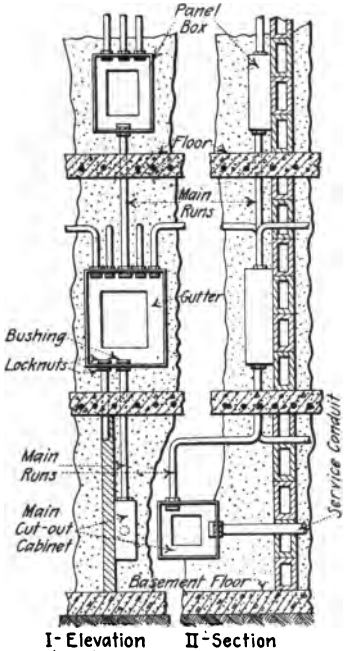


FIG. 290.—Service connection and main run conduits.

28*b*. ¶*II*. INTERIOR CONDUITS. In case of service connections and main runs, this involves running each conduit continuously into a main cut-out cabinet or gutter surrounding the panel board, as the case may be.

28*b*. ¶*III*. INTERIOR CONDUITS. Departure from this rule may be authorized in case of underground services by special permission.

Service connection and main run conduits may be arranged as suggested in Fig. 290. Each run extends continuously between steel cabinets, which are really outlet boxes of a special type.

28*c*. ¶*I*. INTERIOR CONDUITS. Must be first installed as a complete conduit system, without the conductors.

A conduit system should always be first installed complete without the conductors for the reasons given in a preceding paragraph wherein it was noted that if the conductors are

placed within the tubes prior to the completion of the building there is always the possibility that they may be damaged or cannot be withdrawn.

28*d*. ¶*I*. INTERIOR CONDUITS. Must be equipped at every outlet with an *approved* outlet box or plate. At exposed ends of conduit (but not at fixture outlets) where wires pass from the conduit system without splice, joint or tap, an *approved* fitting having separately bushed holes for each conductor must be used. Departure from this rule may be authorized by special permission.

Steel outlet plates and boxes are formed as suggested in Fig. 291. These outlet plates and boxes have three distinct functions. *The first* is to insure the mechanical continuity of the metallic lining of the wire raceways which is provided by the conduit tubes. *The second* is to provide substantial support for the conduit and fixture ends at outlets. *The third* is to complete the electrical continuity of the grounded conduit system.

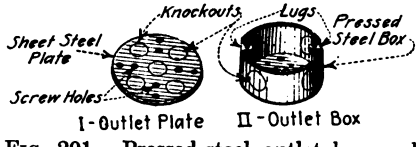


FIG. 291.—Pressed-steel outlet box and outlet plate.

Outlet boxes are preferable to outlet plates because the boxes provide a roomy recess lined with non-combustible material in which taps or splices may be made. Outlet boxes are imperative at switch outlets but the plates may be used at fixture outlets, provided the fixture has a canopy which forms a chamber. Where a lighting appliance, as for instance, a drop cord or rosette, has no canopy, an outlet box with a suitable steel cover should be used.

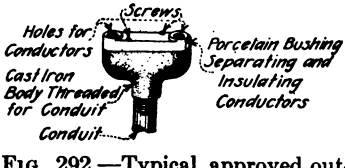


FIG. 292.—Typical approved outlet fittings.

Approved outlet fittings must be used in open-work conduit installations at the terminations of conduit runs as shown at Fig. 288. Iron bushings were formerly approved for protecting conductors against abrasion at conduit ends in exposed work but their use is no longer sanctioned. As shown in Fig.

292, the non-combustible bushing (usually of porcelain) on an outlet fitting serves to insulate the conductors from one another where they emerge from the tube and to maintain a suitable separation between them where they leave the protection of the conduit.

28*d*. ¶*II*. INTERIOR CONDUITS. Outlet plates must not be used where it is practicable to install outlet boxes.

An outlet plate should never be used where it is possible to install an outlet box. As is evident from Fig. 291, a box affords better protection for the conductors. A plate does not provide a steel-lined chamber but does, when the conduits enter it and when they are fitted with locknut and bushings, connect the different sections together electrically and it provides substantial support for the conduit ends, thereby retaining them in position.

28*d*. ¶*III*. INTERIOR CONDUITS. For concealed work in walls and ceilings composed of plaster on wooden joist or stud construction, outlet boxes or plates and also cut-out cabinets must be so installed that the front edge will not be more than one-fourth inch back of the finished surface of the plaster, and if this surface is broken or incomplete it shall be repaired so that it will not show any gaps or open spaces around the edges of the outlet box or plate or of the cut-out cabinet. On wooden walls or ceilings, outlet boxes or plates and cut-out cabinets must be so installed that the front edge will either be flush with the finished surface or project therefrom. This will not apply to concealed work in walls or ceilings composed of concrete, tile or other non-combustible material.

In setting outlet boxes, plates or cabinets for concealed-conduit-wiring installations on plastered surfaces they should always be so arranged that their edges are not more than ¼ in. back of the plastered surfaces and they should fit snugly in the hole. Otherwise the wiring recess thus provided will not be completely lined with metal and the ends of the laths or other combustible material that is exposed may be the source of fire risk. Gaps around the edges of an outlet box may allow a draft to promote a fire if one is started within the box and furthermore may allow a fixture canopy to sink into the hole and contact with the outlet box from which it should in most cases be insulated. It follows that outlet boxes, plates

or cabinets mounted on wood surfaces should have their outer edges flush with or projecting beyond the wood, so as to protect it from the possibility of being ignited.

28*d*. ¶*IV*. INTERIOR CONDUITS. In buildings already constructed where the conditions are such that neither outlet box nor plate can be installed, these appliances may be omitted, providing the conduit ends are bushed and secured.

Where outlet boxes or plates are omitted the conduit ends should be connected (wired) together to insure electrical conductivity of the entire conduit system. They should be supported firmly in position with pipe straps or by other means.

28*d*. ¶*IV*. NOTE. INTERIOR CONDUITS. It is suggested that outlet and fittings having conductive coatings be used in order to secure better electrical contact at all points throughout the conduit system.

Galvanized or sherardized conduit and fittings are preferable, as a rule, for concealed conduit installations because with them good electrical contact is always provided between the components of the system. Where conduit and fittings are enameled, it is always necessary to scrape the enamel, which is a reasonably good insulator, from the outlet boxes and other fittings to insure conductivity. Note that (*Rule* 28*f*, ¶*II*) gas pipes where they enter outlet boxes must be in good electrical connection therewith.

28*e*. ¶*I*. INTERIOR CONDUITS. Metal conduits where they enter junction boxes, and at all other outlets, etc., must be provided with *approved* bushings or fastening plates fitted so as to protect wire from abrasion, except when such protection is obtained by the use of *approved* nipples, properly fitted in boxes or devices.

Conduit bushings are required on the end of every run of conduit terminating in an outlet box unless some other device which accomplishes the same end is provided. The bushings, Figs. 268 and 289 protect the conductors from the sharp edges of the pipe end. These keen edges are formed when the conduit is cut off with a pipe cutter or a hack saw, and although reaming the ends of the tube usually cuts away the sharpest edge, it seldom makes it smooth enough that conductors can rub on it without injury. The bushing is made with a rounded

edge which is not likely to abrade the insulation on the conductor.

28*f*. ¶*I*. INTERIOR CONDUITS. Must have the metal of the conduit permanently and effectually grounded to water piping, gas piping or other suitable grounds, provided that when connections are made to gas piping, they must be on the street side of the meter. If the conduit system consists of several separate sections, the sections must be bonded to each other, and the system grounded, or each section may be separately grounded, as required above. Where short sections of conduit (or pipe of equivalent strength) are used for the protection of exposed wiring on side walls, and such conduit or pipe and wiring is installed as required by No. 26 *e*, the conduit or pipe need not be grounded.

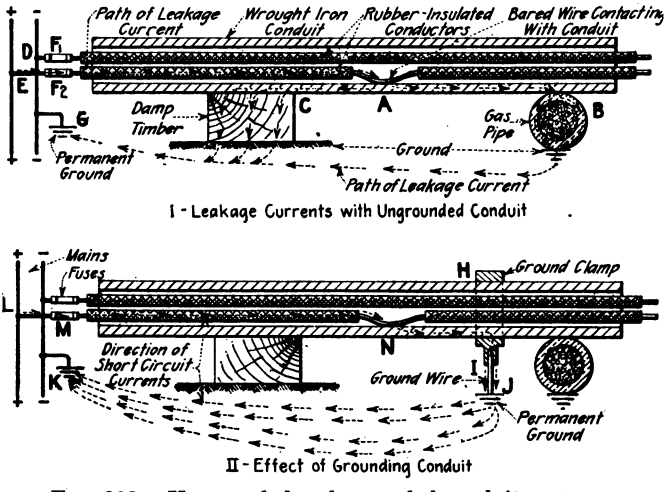


FIG. 293.—Ungrounded and grounded conduit systems.

Effective grounding of a conduit system is necessary to minimize fire hazard. It is impracticable if not impossbile to insulate the conduit of a system from ground; hence, the obvious procedure is to ground it permanently and effectively. The reasons for grounding a metallic conduit system are the same ones that dictate the grounding of motor and generator frames and which are discussed under *Rule* 1*c*, ¶*I*.

What might occur in an ungrounded and a grounded conduit system is illustrated in Fig. 293. The tubes and metal parts

of a conduit system in their ramifications about a building may contact with numerous grounded objects.

EXAMPLE.—The tubing might rest on damp wood, as at *C* in Fig. 293, *I*, or on a gas pipe as at *B*. Now if one of the conductors carried within the system became bared and contacted with the tube as at *A*, and there happened to be another ground *G* on the other conductor (of opposite polarity) of the system, trouble might occur. Note that the one ground at *A* on the positive side of the circuit could not of itself make trouble, provided there were no ground at *G* on the negative side, but in practice there is liable to be a ground on either side of a system. In fact, alternating-current secondary circuits should always be permanently grounded as specified in *Rule* 15*b* and furthermore, the neutral of a direct-current three-wire system should, in practically every case, be grounded as specified in *Rule* 15*a*.

Thus, with conditions as above described, a current might flow via the path EF_2ACG. That is, a current would flow through the damp timber to ground. The current might be of small intensity because it might be limited by the high resistance of the damp timber, but it could be of sufficient intensity to char the timber and yet not operate the cut-out F_2. Ultimately, the timber, *C*, might be ignited and a fire result.

Furthermore, current might flow via the path *EFABG* through the point *B* where the conduit contacts with the gas pipe. The contact might be of such high resistance that the current flowing would not be great enough to operate F_2 but this current might at the same time be such that the arc produced by it at point of contact *B* would burn a hole in the pipe and possibly ignite the gas.

Now, if the conduit system is permanently and effectively grounded as at *HIJ* (Fig. 293, *II*) and one of the wires of the system accidently contacts with the conduit as at *N*, then a large current would flow via the path *LMNIJK* because the resistance of the permanent ground would be very low. This heavy current would almost instantly operate cut-out *M*, disconnecting the location of the trouble from the source of e.m.g. Furthermore, a fuse would not "hold" at *M* until the trouble were corrected.

Not alone does permanently grounding the conduit decrease

fire hazard, but it also may decrease life hazard for the same reasons that grounding a generator or motor frame (*Rule* 1*c*, ¶*I*) or the secondary of a distributing system (*Rule* 15*b*, ¶*I*) gives this insurance. It is obvious then that the ground on a conduit system must be a thorough one.

28*f*. ¶*II*. INTERIOR CONDUITS. Conduits and gas pipes must be securely fastened in outlet boxes, junction boxes and cabinets, so as to secure good electrical connections.

Electrical continuity of the conduit system is essential. It is evident that all of the parts, tubing, outlet boxes, outlet plates, junction boxes and metal cabinets must be electrically connected together so that a ground on the system will afford protection to all parts of it. It is apparent, too, that the joints or points of contact between the different components of the conduit system should be of very low resistance, otherwise grounding will not afford the protection expected of it.

28*f*. ¶*III*. INTERIOR CONDUITS. If conduit, couplings, outlet boxes, junction boxes, cabinets or fittings, having protective coating of non-conducting material such as enamel are used, such coating must be thoroughly removed from threads of both couplings and conduit, and such surfaces of boxes, cabinets and fittings where the conduit or ground clamp is secured in order to obtain the requisite good connection. Grounded pipes must be cleaned of rust, scale, etc., at place of attachment of ground clamp.

28*f*. ¶*IV*. INTERIOR CONDUITS. Connections to grounded pipes and to conduit must be exposed to view or accessible, and must be made by means of *approved* ground clamps.

The methods of connecting ground wires to conduits and to ground pipes may be divided into two general classes: (1) *Connections with approved ground clamps as shown in Fig.* 294. (2) *Special methods which do not involve the use of ground clamps.* Although approved ground clamps of one type or another are ordinarily employed, inspectors will frequently approve ground connections effected with other "home-made" appliances, provided the appliance affords a substantial and reliable attachment between the conduit system and the ground pipe. Some of the methods hereinbefore described

for grounding motor (*Rule* 8*a*, ¶*I*) and generator (*Rule* 1*c*, ¶*I*) frames, three-wire system neutrals (*Rule* 15*a*, ¶*I*) and alternating-current transformer secondaries (*Rule* 15*b*, ¶*I*) may often be used to advantage in grounding conduit.

Ground clamps provide a means of effecting a good electrical and mechanical attachment of the ground wire to the conduit and to the pipe to which the system is grounded. At least one clamp is used on the conduit and one on the pipe which affords the ground. A ground wire is arranged between the two and soldered in the lug of each. The ground clamps should be accessible for inspection so that one may assure himself of their integrity. The method of making up the ground clamp illustrated in Fig. 294 around a pipe or conduit is shown in Fig. 295 which is self-explanatory.

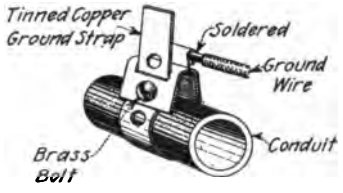


FIG. 294.—One type of approved ground clamp.

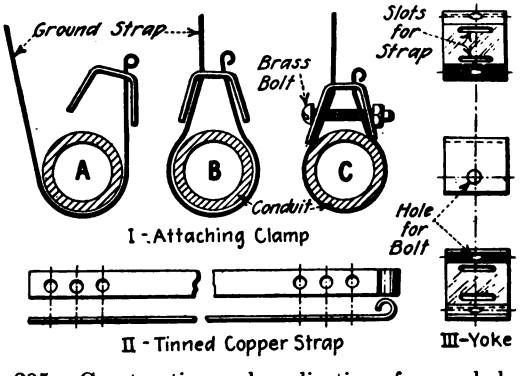


FIG. 295.—Construction and application of ground clamp.

Conduit should be grounded wherever conveniently possible. While one good ground on a system is ordinarily sufficient it is always desirable to provide additional grounds wherever a conduit run lies near to or contacts with a steel beam or column, or a grounded pipe. At all combination outlets,

that is, at fixture outlets through which a gas pipe extends, the outlet box must be electrically connected to the gas pipe as outlined in *Rule* 28*f*, ¶*II*.

28*f*. ¶*V*. INTERIOR CONDUITS. Ground wires must be of copper, at least No. 10 B. & S. gage (where largest wire contained in conduit is not greater than No. 0 B. &. S. gage), and need not be greater than No. 4 B. & S. gage (where largest wire contained in conduit is greater than No. 0 B. & S. gage). They shall be protected from mechanical injury.

The sizes of conduit ground wires are determined to a certain extent by the element of mechanical strength. That is, every ground wire should be at least large enough so that it cannot be easily broken, hence, No. 10 B. & S. gage copper wire is the smallest that should ever be used. In case of a ground on a conduit system, as illustrated at *N*, Fig. 293, *II*, the ground wire will carry the heavy current for a very short interval only, because the cut-out should operate soon after the heavy current starts to flow. But it is evident that the current that the ground wire *may* carry will be determined to some extent by the carrying capacity of the cut-out at *M*, Fig. 293, *II*. On a large extensive system it is then obvious that this cut-out will be of greater capacity than in a small system; hence the size of the ground wire should be proportioned with some regard to the size of the largest wire in the conduit system. Copper should always be used for ground wire, because iron wire may rust asunder.

In installing conduit ground wires, mechanical precaution only is necessary, that is, the wires need not be run on insulators but can be protected by wooden boxing or by molding. The ground wire should not be protected with iron pipe or conduit for the same reasons that lightning-arrester ground wires (*Rule* 5*c*, ¶*II*) and the single wire of an alternating-current system (*Rule* 5*c*, ¶*I*) should never be run in conduit. Ground wires should preferably be kept away from inflammable materials. Although it is not necessary from an electrical standpoint to insulate ground wires, it is the practice in some localities to run them on porcelain insulators because this often prevents interference by persons who have respect for any electrical conductor carried on porcelain.

28*f*. ¶*V*. NOTE. INTERIOR CONDUITS. The ground on the conduit system is not to be considered as a ground for a secondary system (see No. 15).

28*g*. ¶*I*. INTERIOR CONDUITS. Junction boxes must always be installed in such a manner as to be accessible. Such boxes are considered to be accessible when installed in an attic that has sufficient head room, but which is reached only by a portable ladder and permanent hatch.

Junction boxes should always be accessible both during the construction of the building and after it is completed, so that the wires in the conduit system can be readily removed and replaced. If the junction boxes are not accessible, it is apparent that one of the principal advantages of the conduit method of wiring will be defeated. A box is not accessible if it is necessary to remove parts of floor or to make holes in ceilings or partitions to get to it.

28*h*. ¶*I*. INTERIOR CONDUITS. All elbows or bends must be so made that the conduit will not be injured. The radius of the curve of the inner edge of any elbow not to be less than three and one-half inches. Must have not more than the equivalent of four quarter bends from outlet to outlet, the bends at the outlets not being counted.

There should not be more than four quarter bends between any two outlet boxes. If the route of any run is such that it would necessarily contain more bends than this, accessible junction boxes should be inserted at locations in the run so that there will not be more than four bends between any two outlets.

28*i*. INTERIOR CONDUITS. Size of conduits for the installation of wires and cables.

NUMBER OF CONDUCTORS IN SYSTEM

Size B. & S.	One conductor in a conduit. Size conduit, in.	Two conductors in a conduit. Size conduit, in.	Three conductors in a conduit. Size conduit, in.	Four conductors in a conduit. Size conduit, in.
	Electrical trade size	Electrical trade size	Electrical trade size	Electrical trade size
14	½	½	¾	¾
12	½	¾	¾	¾
10	½	¾	¾	1
8	½	1	1	1
6	½	1	1¼	1¼
5	¾	1¼	1¼	1¼
4	¾	1¼	1¼	1½
3	¾	1¼	1¼	1½
2	¾	1¼	1½	1½
1	¾	1½	1½	2
00	1	1½	2	2
00	1	2	2	2½
000	1	2	2	2½
0000	1¼	2	2½	2½
CM				
200000	1¼	2	2½	2½
250000	1¼	2½	2½	3
300000	1¼	2½	2½	3
400000	1¼	3	3	3½
500000	1½	3	3	3½
600000	1½	3	3½	.....
700000	2	3½	3½	.....
800000	2	3½	4	.....
900000	2	3½	4	.....
1000000	2	4	4	.....
1250000	2½	4½	4½	.....
1500000	2½	4½	5	.....
1750000	3	5	5	.....
2000000	3	5	6	.....

TWIN CONDUCTOR

Size B. & S.	One conductor in a conduit. Size conduit, in.	Two conductors in a conduit. Size conduit, in.	Three conductors in a conduit. Size conduit, in.	Four conductors in a conduit. Size conduit, in.
	Electrical trade size	Electrical trade size	Electrical trade size	Electrical trade size
14	½	¾	1	1
12	½	¾	1	1¼
10	¾	1	1¼	1¼

3 CONDUCTOR CONVERTIBLE SYSTEM

Size of conductors		Size conduit, in.
Two conductor size B. & S.	One conductor size B. & S.	Electrical trade size
14	10	¾
12	8	¾
10	6	1
8	4	1
6	2	1¼
5	1	1¼
4	0	1½
3	00	1½
2	000	1½
1	0000	2
0	250000	2
00	350000	2½
000	400000	2½
0000	550000	3
250000	600000	3
300000	800000	3
400000	1000000	3½
500000	1250000	4
600000	1500000	4
700000	1750000	4½
800000	2000000	4½

SINGLE CONDUCTOR COMBINATION

NOTE.—Where special permission has been given in accordance with No. 26, *p*, the following table to apply.

No. of wires	Size conduit, in. Electrical trade size
3 No. 14 R.C. solid	½
5 No. 14 R.C. solid	¾
10 No. 14 R.C. solid	1
18 No. 14 R.C. solid	1¼
24 No. 14 R.C. solid	1½
40 No. 14 R.C. solid	2
74 No. 14 R.C. solid	2½
90 No. 14 R.C. solid	3

29. METAL MOULDINGS.

(*See also No.* 26 *k to m. For construction of Mouldings see No.* 60)

The advantages of metal molding over wood molding are: (1) *It is non-combustible.* (2) *It occupies less space.* (3) *It affords greater mechanical protection.* As noted in a preceding paragraph, the use of wood molding is not allowed in some cities. A metal-molding installation is illustrated in Fig. 296 which indicates its adaptability for making extensions to existing wiring systems.

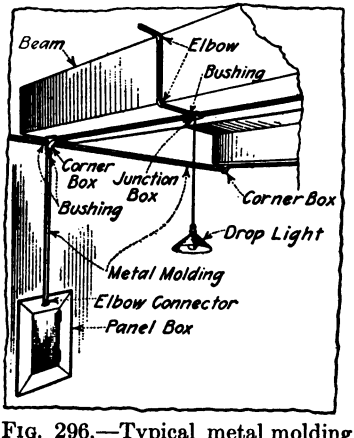


FIG. 296.—Typical metal molding installation.

The requirements for the installation of metal molding are, in general, similar to those for wrought-iron conduit, because the function of the conduit is substantially the same as that of the molding. It is to provide a metal-lined raceway for the protection of the conductors.

The maximum wattage permissible on a metal-molding circuit is 1,320 (*Rule* 26*l*, ¶*I*), and the maximum permissible voltage is 300 (*Rule* 26*l*, ¶*I*).

29*a*. ¶*I*. METAL MOULDINGS. Must be continuous from outlet to outlet, to junction boxes, or *approved* fittings designed especially for use with metal mouldings, and must at all outlets be provided with *approved* terminal fittings which will protect the insulation of conductors from abrasion, unless such protection is afforded by the construction of the boxes or fittings.

Metal-molding systems must be continuous from outlet to outlet for the same reasons (*Rule* 28*b*, ¶*I*) that it is essential that conduit systems be thus continuous. As with conduit systems, the metal-molding runs must be continuous both electrically and mechanically.

Outlet boxes and approved fittings for metal-molding wiring are manufactured in a great variety of forms; see the author's AMERICAN ELECTRICIANS' HANDBOOK. All splices in the system must be made within one of these fittings or boxes, since splices are not permitted within the molding itself. Wherever a metal-molding system joins wiring arranged in accordance with the knob-and-tube, conduit or open-work methods, the junction must be effected in an approved junction box of which there are a variety of types, made especially for the purpose. Wherever conductors leave the metal-molding system to serve an energy-consuming device, an approved fitting which suitably insulates the wires from one another and protects them from abrasion at the point where they emerge from the molding system must be used.

29*b*. ¶*I*. METAL MOULDINGS. Such moulding where passing through a floor must be carried through an iron pipe extending from the ceiling below to a point five feet above the floor, which will serve as an additional mechanical protection and exclude the presence of moisture often prevalent in such locations.

Where metal-molding runs pass through floors they should be protected as suggested in Fig. 297. The iron-pipe protective tubing is installed for two reasons: (1) *To afford mechanical protection;* (2) *to prevent scrub water from entering the molding.*

In installing metal-molding protection on side walls the continuous length of iron pipe should, where the molding might be exposed to mechanical injury, extend to a distance of at

least 5 ft. above the floor and also downward through the ceiling below, and beyond the ceiling a few inches, Fig. 297, *I*. The protecting pipe can be held to the supporting surface with pipe straps. Metal molding is not of great mechanical strength, since (*Rule* 60*d*) the backing is formed of sheet steel 0.050 in. (that is, between 3/64 in. and 1/16 in.) thick, minimum, and the capping of metal 0.040 in. (that is, between 1/32 in. and 3/64 in.) thick. In locations where appearance is a factor and the metal molding on a side wall is not liable to mechanical

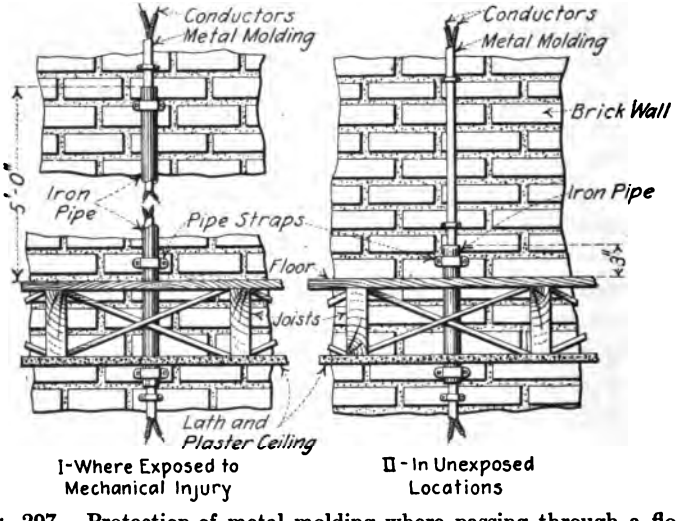


FIG. 297.—Protection of metal molding where passing through a floor.

injury, as in residences and in office buildings, and where it is obvious that the mechanical strength of the molding and backing is of itself adequate, the iron-pipe protection may ordinarily extend from the ceiling below to a point only 3 in. above the floor (*Rule* 29*b*, ¶*II*), as suggested in Fig. 297, *II*. In warehouses and factories where mechanical interference is probable, the protection should be extended at least 5 ft., as shown in Fig. 297, *I*.

29*b*. ¶*II*. METAL MOULDINGS. Where the mechanical strength of the moulding itself is adequate, this ruling may be modified to require

the protecting piping from the ceiling below to a point at least three inches above the flooring.

29*b*. ¶*III*. METAL MOULDINGS. Where such mouldings pass through a partition the iron pipe required for passing through floors may be omitted and the moulding passed directly through, providing the partition is dry and the moulding is in a continuous length with no joint or coupling within the partition.

The protection required where metal molding passes through partitions is illustrated in Fig. 265 and has been described.

29*c*. ¶*I*. METAL MOULDINGS. Backing must be secured in position by screws or bolts, the heads of which must be flush with the metal.

The methods of supporting metal-molding backing are illustrated in Fig. 298. In any case, the head of the bolt or screw which extends into the molding must not project into

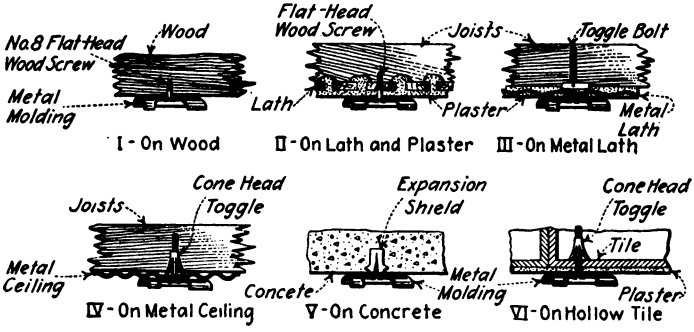


FIG. 298.—Methods of supporting metal molding.

the wiring space or offer a sharp edge that might cut the insulation on the conductors.

29*d*. ¶*I*. METAL MOULDINGS. Must have the metal of moulding permanently and effectually grounded to water piping, gas piping, or other suitable grounds, provided that when connections are made to gas piping, they must be on the street side of the meter. If the metal moulding system consists of several separate sections, the sections must be bonded to each other and the system grounded, or each section may be separately grounded, as required above.

Metal molding must be grounded for the same reasons that dictate the grounding (*Rule* 28*f*, ¶*I*) of conduit systems.

Positive grounding decreases fire and life hazard. The ground-wire connection at the metal molding is effected with a special ground clamp as shown in Fig. 299, *III*. At the location where the ground wire is connected to the gas or water pipe affording the ground, a suitable ground clamp, is ordinarily (Figs. 294 and 295) used. The ground wire should be soldered in each of these clamps.

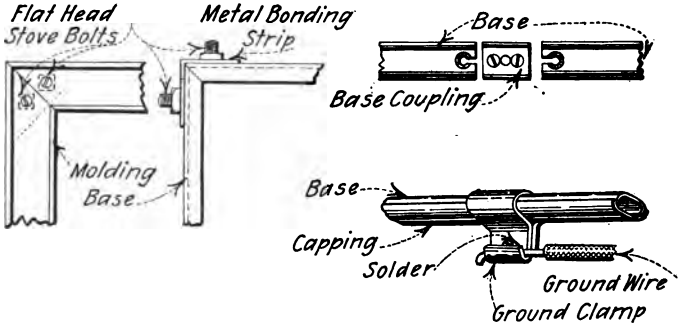


FIG. 299.—Methods of bonding and grounding metal molding.

29*d*. ¶*II*. METAL MOULDINGS. Metal mouldings and gas pipes must be securely fastened to outlet boxes, junction boxes and cabinets, so as to secure a good electrical connection. Moulding must be so installed that adjacent lengths of moulding will be mechanically and electrically secured at all points.

The metal-molding system must be electrically continuous for the same reasons that a conduit system should be electric-

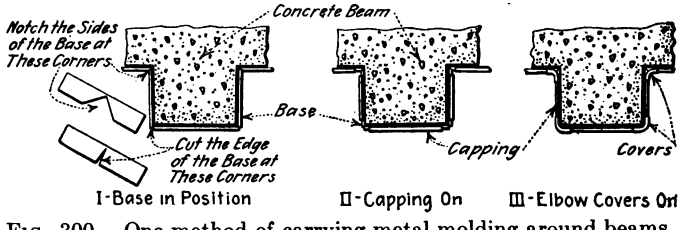


FIG. 300.—One method of carrying metal molding around beams.

ally continuous (*Rule* 286, ¶ *I*). To insure this condition, the different lengths of metal molding must be firmly joined together so as to constitute a good electrical contact and similar

joints must be made at all outlet boxes. The fittings regularly furnished by the metal-molding manufacturers accomplish this result. In Fig. 299, *II*, is shown the method of joining abutting ends of metal-molding backing. A method of making an improvised corner connection is suggested in Fig. 299, *I*. Fig. 300 shows one of the methods of carrying a metal-molding run around a concrete beam.

29*d*. ¶*III*. METAL MOULDINGS. If metal moulding, couplings, outlet boxes, junction boxes, cabinets or fittings having protective coating of non-conducting material such as enamel are used, such coating must be thoroughly removed from the threads of couplings and metal mouldings, and from the surfaces of boxes, cabinets and fittings, where the metal moulding or ground clamp is secured in order to obtain the requisite good connection. Grounded pipes must be cleaned of rust, scale, etc., at the place of attachment of the ground clamp.

29*d*. ¶*IV*. METAL MOULDINGS. Connection to grounded pipes and to metal mouldings must be exposed to view, or accessible, and must be made by means of *approved* ground clamps.

29*d*. ¶*V*. METAL MOULDINGS. Ground wires must be copper, at least No. 10 B. & S. gage. They shall be protected from mechanical injury.

29*e*. ¶*I*. METAL MOULDINGS. Must be installed so that for alternating systems the two or more wires of a circuit will be in the same metal moulding.

29*e*. ¶*I*. NOTE. METAL MOULDINGS. It is suggested that this be done for direct systems also, so that they may be changed to the alternating system at any time, induction troubles preventing such changed if the wires are in separate mouldings.

The preceding requirements relating to the electrical continuity, grounding and number of wires in a metal molding system are dictated by the same conditions which are responsible for similar requirements for rigid conduit systems. See elsewhere the discussion relating to these conditions.

30. FIXTURES.

(*For construction of Fixture Wires see No.* 52. *For construction of Fixtures see No.* 77)

30*a*. ¶*I*. FIXTURES. When supported at outlets in metal conduit, armored cable, or metal moulding systems, or from gas piping or any grounded metal work, or when installed on metal walls or ceilings, or on plaster walls or ceilings containing metal lath, or on walls or ceilings in fireproof buildings, must be insulated from such supports by *approved*

insulating joints placed as close as possible to the ceilings or walls. The insulating joint may be omitted in conduit, armored cable or metal moulding systems with straight electric fixtures in which the insulation of conductors is the equivalent of insulation in other parts of the system, and provided that *approved* sockets, receptacles or wireless clusters are used of a type having porcelain or equivalent insulation between live metal parts and outer metal shells, if any.

Insulating joints should be interposed as shown in Fig. 301 and other illustrations, in the stem of an electric fixture between the fixture and any grounded metal work or conducting material upon which it may be supported. That is, an insulating joint is always required when a fixture is supported from a grounded object which would ground the metal work of the fixture. Obviously, gas piping and conduit systems are effectively grounded.

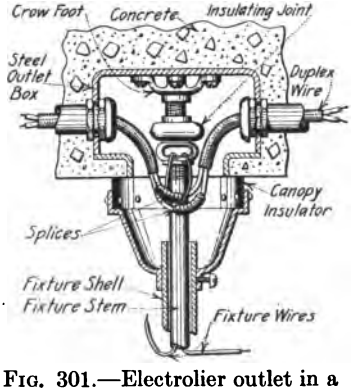


FIG. 301.—Electrolier outlet in a concrete ceiling.

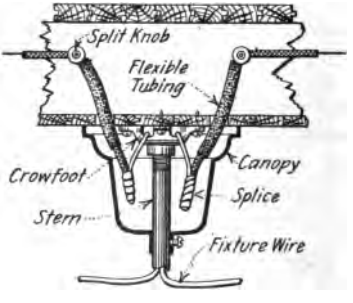


FIG. 302.—Electrolier on a wooden ceiling.

An insulating joint is not required when a fixture is supported from an undergrounded surface or support, as shown in Fig. 302; hence, insulating joints are not required for straight electric fixtures hung from wood ceilings or walls, or from lath and plaster ceilings or walls provided the wiring is done by the knob-and-tube, open-work, or molding methods. If the wiring is in accordance with the conduit method an insulating joint is required.

The reasons why fixtures should be insulated from ground, that is, the reasons that dictate the use of insulating joints are

these: The electric fixture is probably the weakest member, electrically, in the wiring system. The fixture wire within it has relatively thin insulation and is drawn into cramped places and in some cases past the sharp edges of metal parts composing the fixture. Hence, as might be expected and as experience has shown, contact between the metal of the fixture wire and the metal parts of the fixture is very liable to occur. If the fixture is insulated from ground, the difficulty will be localized to within the fixture. The relative weakness of the fixture-wire insulation is then the real element that dictates the insulation of fixtures from ground. If wire having the

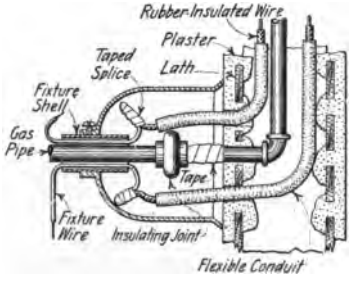


FIG. 303.—Method of supporting a combination bracket fixture in a knob-and-tube wiring installation.

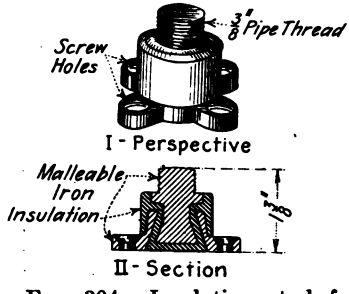


FIG. 304.—Insulating stud for fixtures. (Used instead of a crowfoot and an insulating joint in steel outlet boxes for straight electric fixtures.)

same insulation as that on all other parts of the system is used in the fixture, its insulation from ground is not necessary.

Insulating joints, as shown in a number of the illustrations, may be divided into two general classes: (1) *Those for straight electric fixtures, Fig.* 301, *which are blanked, that is, they have no opening through them;* (2) *those for combination fixtures, Fig.* 303, *which have a hole through them to admit the gas to the fixture.*

Insulating studs, Fig. 304, may be used in conduit installations instead of insulating joints. For example, an insulating stud is shown in Fig. 305 and could have been used instead of the insulating joints and crowfoot in the installation indicated in Fig. 301.

Where wire of the same insulation as that of the balance of the system is carried into the fixture the insulating joint may be omitted. That is, if No. 14 rubber-insulated wire like that used in the branch circuits is used for fixture wiring, it is not necessary in any case to insulate the fixture from ground, provided the live metal parts of the fixture are thoroughly insulated from the shells and similar "dead" metal parts.

¶30*a*. ¶*II*. FIXTURES. Gas pipes must be protected above the insulating joint by *approved* insulating tubing, and where outlet tubes are used they must be of sufficient length to extend below the insulating joint, and must be so secured

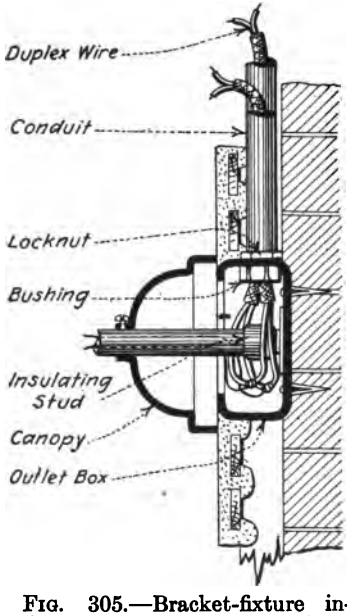


FIG. 305.—Bracket-fixture installation. (Conduit wiring in a lath-and-plaster surface.)

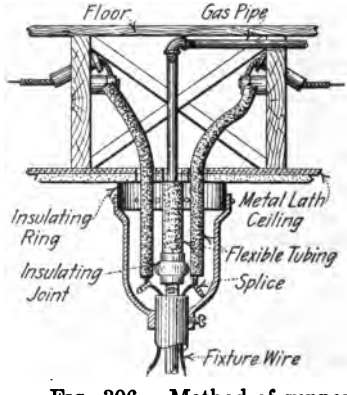


FIG. 306.—Method of supporting a combination fixture on a metal-lath ceiling.

that they will not be pushed back when the canopy is put in place.

Gas pipes above the insulating joint should have an insulating protection as shown in Figs. 303 and 306. This protection may be either a serving of tape (Fig. 303), a piece of flexible tubing (Fig. 306), or a porcelain tube. The flexible tubing, if this material is used, may be split and placed around the pipe and then bound in position with friction tape. Where

all of the gas pipe exposed at the outlet is below the insulating joint as shown at Fig. 301, insulating protection on the pipe is unnecessary.

Metallic cements or paints should not be used on the gas-pipe threads of insulating joints because such materials may run down through the hole in the joint and bridge across the insulating material, thereby short-circuiting the joint. For these reasons, white and red lead are unsuitable. An insulating paint or cement—asphaltum for example—may be employed.

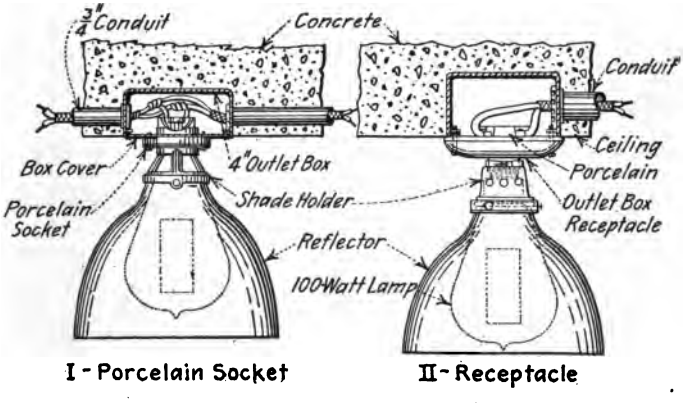


FIG. 307.—Showing wiring of ceiling fixtures.

The wiring at bracket outlets is shown in Figs. 303 and 305. Fig. 303 illustrates a knob-and-tube "combination fixture" installation but since there is a gas pipe at the outlet an insulating joint must be used. Fig. 305 shows an outlet box at a conduit-wiring "straight-electric" bracket outlet, an insulating joint being used to electrically separate the fixture from the grounded conduit system.

Ceiling-fixture outlet wiring is shown in Fig. 307. The sockets and shade holders, which in this installation comprise the "fixture," are insulated, in each of the installations shown, from the conduit outlet box by porcelain in lieu of insulating joints.

Fixture wiring in an exposed conduit installation is shown in Fig. 308*A*. Insulating joints and canopy insulators are required.

30*a*. ¶*III*. FIXTURES. Where insulating joints are required, fixture canopies of metal must be thoroughly and permanently insulated from metal walls or ceilings, or from plaster walls or ceilings on metal lathing, and from outlet boxes.

The function of a canopy insulator is to prevent the grounding of a fixture through the metal work of the canopy contacting with a conducting grounded surface or object. Obviously,

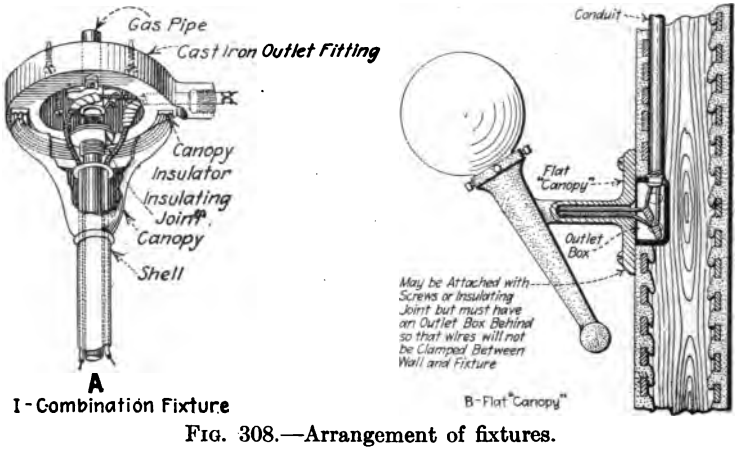


FIG. 308.—Arrangement of fixtures.

a fixture may be grounded through its canopy as well as through its stem, necessitating in some cases the inclusion of an *insulating joint* between the canopy and the supporting surface as well as in the stem of a fixture. Where conditions demand their installation, it does no good to insert an insulating joint in the stem unless one is also arranged between the canopy and the supporting surface.

Canopy insulators should be used as shown in Figs. 301, 306 and 309 where a fixture canopy might ground a fixture. These insulators usually comprise a strip of fiber or similar insulating material attached around the circumference of the canopy as shown in Fig. 310. Canopy insulators are not

required when the canopy will rest against a plaster-on-wood-lath or on a wood surface, but where the canopy will rest against a plaster-on-metal-lath surface or where it might contact with an outlet box the insulator is required. Canopies are not insulated from ordinary plas-

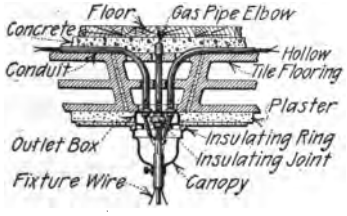


FIG. 309.—Combination gas-and-electric ceiling fixture outlet in a hollow tile ceiling.

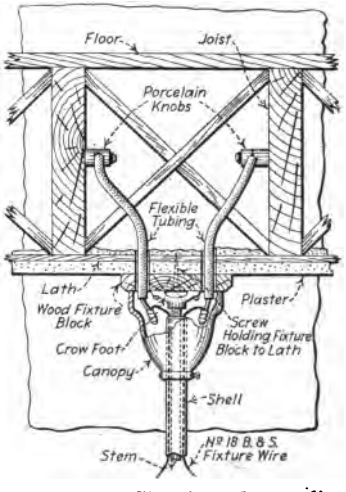


FIG. 309*a*.—Showing the application of a wood fixture block.

tered surfaces in fireproof buildings because dry plaster is a fairly good insulator, but where the plaster is on metal lath then there is always danger of metallic contact and canopy insulators should be used.

A dry wood block fastened to the supporting surface may be used in lieu of a canopy insulator in certain cases provided the screws supporting the block do not contact with the metal parts of the fixture. Where a "hickey" is mounted on such a block, the screws holding the hickey should not extend through the block.

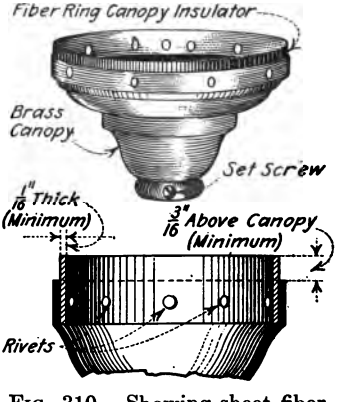


FIG. 310.—Showing sheet fiber canopy insulator.

A canopy insulator must extend around the entire circumference of the canopy unless it is necessary to cut away a relatively small portion of it

(in open and molding wiring) for the admission of the conductors. The so-called "bug" insulators which were formerly used and which insulated the canopy at only a few points around its circumference are no longer acceptable.

30*a*. ¶*IV*. FIXTURES. Canopy insulators must be securely fastened in place, so as to separate the canopies thoroughly and permanently from the surfaces and outlet boxes from which they are designed to be insulated.

In attaching insulators to canopies they may be either secured with small rivets as shown in Fig. 310 or one of the special forms of canopy insulators may be applied. Fig. 311 illustrates one of these special forms which is very popular in certain sections of the country. The metal of the canopy is

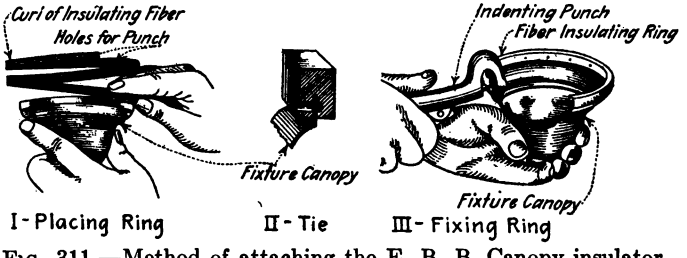


FIG. 311.—Method of attaching the E. B. B. Canopy insulator.

deformed with a special punch so that it engages in the holes in the insulating ring. It has the advantage that rivets, which sometimes result in undesirable accidental contacts, are not used.

Where molding or open wiring enters a canopy, the canopy should be cut to provide for its reception so that there can be no possibility of the sharp edges of the canopy cutting into the insulation on the conductors.

30*a*. ¶*V*. FIXTURES. For fixtures which are not attached to gas pipes or conduit unless outlet boxes or other *approved* fittings which will give proper support for fixtures are used, a seven-eighths inch block must be fastened between studs or floor timbers flush with the back of lathing to hold tubing and to support fixtures. When this cannot be done, wooden base blocks, not less than ¾ inch in thickness, securely screwed to lathing, must be provided.

Supporting boards and base blocks are shown in Figs. 279 and 309*A* and are described in the text accompanying them.

30*a*. ¶*VI*. FIXTURES. Fixtures having so-called flat canopies, tops or backs, will not be approved for installation, except where outlet boxes are used.

NOTE.—A "Flat canopy" fixture supported from an outlet box is shown in Fig. 308B.

30*b*. ¶*I*. FIXTURES. When installed out of doors, must be of water-tight construction.

30*c*. ¶*I*. FIXTURES. Fixture wires must be not smaller than No. 18 B. & S. gage, and must have an *approved* rubber insulating covering (see No. 52).

Wire for wiring fixtures should obviously have the best insulation because such conductors always lie close to the metal work of the fixture. They are fished through restricted spaces, pulled around sharp bends and subjected to other abuses; hence, rubber insulation is used. No. 18 wire is the minimum size permissible in wiring fixtures, and most fixtures are wired with this size. Ordinarily, this is necessary in the case of combination gas-and-electric fixtures, because the space between the gas pipe and the fixture casing, as shown in Fig. 303, is frequently so small that wires larger than No. 18 could not be accommodated. If fixture shells were made large enough to accommodate relatively large wires, for instance, No. 14, they would be bulky and unsightly.

30*c*. ¶*II*. FIXTURES. In wiring certain designs of show-case fixtures, ceiling bulls-eyes and similar appliances in which the wiring is exposed to temperatures in excess of 120 degrees Fahrenheit (49 degrees Centigrade), from the heat of the lamps, *approved* slow-burning wire must be used. All such forms of fixtures must be submitted for examination, test and approval before being introduced for use.

30*d*. ¶*I*. FIXTURES. Supply conductors, and especially the splices to fixture wires, must be kept clear of the grounded part of gas pipes, and, where shells or outlet boxes are used, they must be made sufficiently large to allow the fulfillment of this requirement.

Wiring in and adjacent to fixtures should never be permitted to contact with grounded portions of gas pipes because of the possibility of a hole being burnt in the gas pipe by a conductor grounded on it and the gas then being ignited by the arc.

30*e*. ¶*I*. FIXTURES. Must, when wired on the outside have the conductors so secured as not to be cut or abraded by the pressure of the fastenings or motion of the fixture.

30*e*. ¶*II*. FIXTURES. Must not, when wired on the outside, be used in show windows or in the immediate vicinity of especially inflammable stuff.

30*e*. ¶*III*. FIXTURES. Chain fixtures must be wired with flexible conductors.

Chain fixtures should be wired with flexible conductors as suggested in Fig. 312, because if solid wires are used they are liable to be weakened and broken off by the swaying of the fixture.

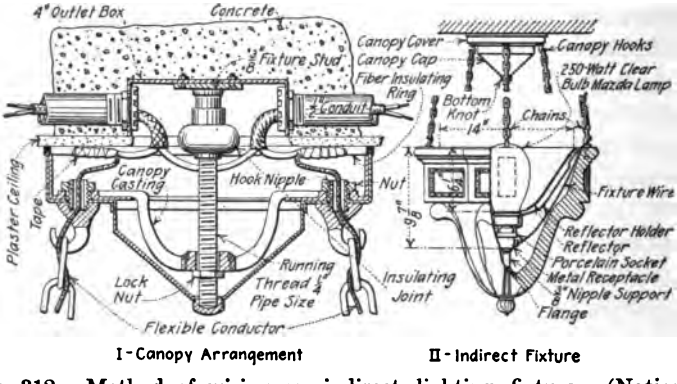


FIG. 312.—Method of wiring an indirect lighting fixture. (National *X*-ray Reflector Company.)

30*f*. ¶*I*. FIXTURES. Wires of different systems must never be contained in or attached to the same fixture, and under no circumstances must there be a difference of potential of more than 300 volts between wires contained in or attached to the same fixtures.

30*g*. ¶*I*. FIXTURES. Must be free from short circuits between conductors and from contacts between conductors and metal parts of fixtures, and must be tested for such conditions before being connected to supply conductors.

Fixtures should be tested both before and after installation to insure that they contain no grounded or short-circuited conductors. Methods whereby these tests may be readily effected are described in the author's AMERICAN ELECTRICIANS' HANDBOOK. Time and expense are always saved by conduct-

ing such tests because, as hereinbefore noted, fixtures are peculiarly prone to troubles which should always, if possible, be located and cleared before the fixtures are erected and connected to the wiring system.

31. SOCKETS.

(For construction of Sockets see No. 72)

The key socket constitutes another source of trouble in wiring systems. In spite of the fact that the construction of this device has been greatly improved in late years it is still a relatively delicate mechanism and may be expected to cause difficulties if it is subject to severe usage. For these reasons, it is advisable *not* to use key sockets if keyless sockets can be made to serve.

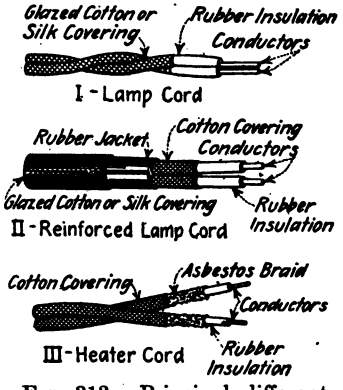


FIG. 313.—Principal different kinds of flexible cord.

Socket threads are cut with either ⅛-in. or ⅜-in. standard pipe threads. Sockets having ⅛-in. threads may be used on fixtures while those with a ⅜-in. thread (which have a 13/32-in. diameter hole) may be used for reinforced lamp cord Fig. 313, *II*, hence, for pendants or for portable lamps.

31*a*. ¶*I*. SOCKETS. In rooms where inflammable gases may exist the incandescent lamp and socket must be enclosed in a vapor-tight globe, and supported on a pipe-hanger, wired with *approved* rubber-covered wire soldered directly to the circuit.

Sockets in places where there may be inflammable gases should be enclosed in a vapor-tight globe, Fig. 314 (vaporproof globes of different types are shown in Fig. 315). Some of the places in which there are liable to be inflammable gases and where, therefore, vaporproof globes should be used, are oil storage rooms, gasoline sheds, oil refineries, paint storage vaults, etc. The vaporproof globes should be used where

inflammable gases *may* exist. It is not necessary that such gases actually exist to justify the installation of the globes.

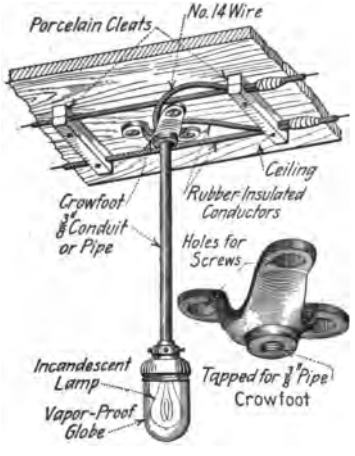


FIG. 314.—Showing vaporproof globe supported on a pipe hanger.

Where the lamp in a place where there are inflammable gases is to be supported directly against the wall or ceiling, a vaporproof globe of the type suggested in Fig. 315, *III*, can be used. It can be fastened by screws through the flange directly to the supporting surface.

Where vaporproof globes are to be supported at a considerable distance from the ceiling, as shown in Fig. 314, a pipe support must be provided to prevent the imposition of a stress, due to the weight of the vaporproof globe, on the conductors, which are relatively fragile and are liable to be broken, particularly

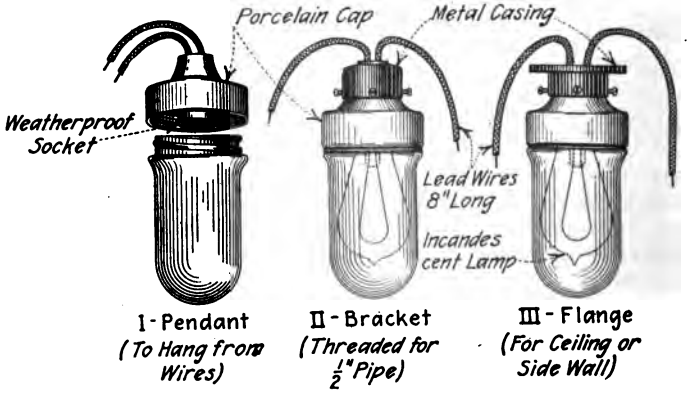


FIG. 315.—Vapor-tight of "vaporproof globes" of different types.

if the globe were permitted to swing on the conductors. The supporting pipe should be as short as feasible to prevent its

being struck accidentally and knocked off. The wires within the pipe connecting to the lamp should be stranded and at least No. 14 gage in size. They should be served with tape where they emerge from the pipe and crowfoot to protect them from abrasion. Where corrosive vapors exist, it is advisable to seal the top of the pipe with a waterproof insulating compound to prevent their entry.

The iron pipe support is sometimes omitted where a vaporproof globe, such as that in Fig. 315, *I*, is supported by two No. 14 conductors twisted together so that they jointly sustain the weight of the globe. FACTORY MUTUAL COMPANY'S WIRING RULES suggest that, in certain cases, this construction is preferable to that involving the use of the pipe hanger.

31*b*. ¶*I*. SOCKETS. In damp or wet places, or where exposed to corrosive vapors, weatherproof sockets especially approved for the location must be used. Unless made up on fixtures they must be hung by separate *stranded* rubber-covered wires not smaller than No. 14 B. & S. gage, which should preferably be twisted together when the pendant is over three feet long.

Weatherproof sockets are made either of porcelain or of an insulating composition. They are provided, as shown in Fig. 316, with rubber-insulated leads molded into them. These leads are ordinarily 8 in. long, but may on special order be obtained of any reasonable length. Weatherproof sockets are not provided with key switches because a socket having a key switch in it cannot be "weatherproof." The porcelain sockets are the cheaper but those of composition are better because they are stronger. However, grease and oils have a deleterious effect on the composition materials, rendering their use inadvisable in certain locations.

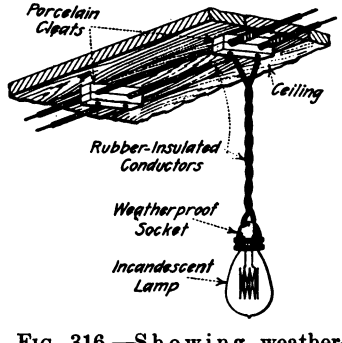


FIG. 316.—Showing weatherproof socket suspended from cleat with No. 14 stranded R.C. wire.

Sockets in damp or wet places must be of the weatherproof

type supported on No. 14 flexible conductors as suggested in Figs. 316 and 317. Some of the places that are ordinarily considered as damp or wet are: dye works, tank rooms, pumping rooms and similar places.

Key sockets should not be used in damp places because the moisture enters the mechanism through the key slot. It may condense, filling the socket with water and short-circuiting it.

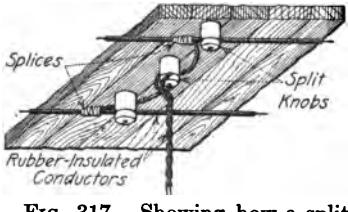


FIG. 317.—Showing how a split knob may constitute an independent support. (Note that in some cities the inspection departments require that pendant conductors arranged as above be supported by "cord buttons;" split knobs are not approved.)

31*b*. ¶*II*. SOCKETS. These wires must be soldered direct to the circuit wires but supported independently of them.

The wires supporting weatherproof sockets should be soldered directly to the main leads but supported on independent insulators. The independent support may be a cleat installed especially for holding up the pendant as shown in Fig. 316, or it may be a pair of cleats, or a split knob, provided as shown in Fig. 317.

31*c*. ¶*I*. SOCKETS. Sockets and receptacles installed over specially inflammable stuff or where exposed to flyings of combustible material, must be of the keyless type, and, unless individual switches are provided, must be installed at least seven and one-half feet above the floor, or must be so located or guarded that the lamps cannot be readily backed out by hand.

31*c*. ¶*II*. SOCKETS. Departure from this rule may be authorized only by special permission in writing.

Key sockets should never be used where inflammable dusts exist, that is, they should not be installed in flour mills, in wood-working shops or in similar places. Keyless sockets should be used instead. Those of the brass-shell type are preferable to the composition or porcelain sockets because they are much less liable to breakage, and should be used unless they will be exposed to moisture.

31*d*. ¶*I*. SOCKETS. When the socket is not attached to a fixture, the inlet if threaded must be not less than ⅜ inch pipe size, and must be provided with an *approved* insulating bushing.

Sockets not on fixtures should have ⅜-in. holes so that reinforced lamp cord or two No. 14 wires, as shown in Fig. 318, may enter the socket.

32. FLEXIBLE CORD.

(*For construction of Flexible Cord see No.* 51)

Flexible cord is, necessarily, no matter how well it may be insulated, of rather delicate construction. The bending of the cord due to its continued movement may break the small wires which comprise the stranded conductor within. Then these sharp ends work through the insulation and possibly into contact with the strands of the conductor of opposite polarity, causing a short-circuit. The insulation may ignite and a fire result. Hence, flexible cord should be used only when more substantial conductors cannot be utilized. The two conductors of opposite polarity in a flexible cord lie very close together, rendering unusual precautions necessary. To sum the matter: It may be stated that flexible cord is a very undesirable material from a fire hazard standpoint—but it appears to be a necessary material, so that its use, subject to certain restrictions, must be sanctioned.

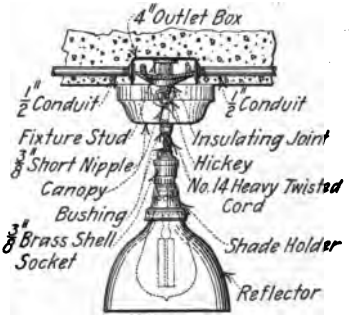


FIG. 318.—Showing No. 14 conductors carried into socket.

32*a*. ¶*I*. FLEXIBLE CORD. Must have an *approved* insulation and covering.

Flexible cords having different types of insulation and of different constructions are made for different service. The matter of the construction of these different sorts of cords is covered very fully in *Rule* 51.

The three principal types of flexible cord are, Fig. 313: (1) *Drop or lamp cord.* This consists of a pair of insulated stranded wires twisted together. Each wire has a serving of cotton thread and is then coated with rubber insulation and given a woven cotton serving for mechanical protection. Two such conductors are twisted together. A cord of this construction is used only for short pendants in dry places hanging freely in air. (2) *Reinforced or portable cord.* This consists of a cord made like the drop cord described above except that in addition it has molded over the two twisted conductors an additional coating of rubber and then over this is served (for mechanical protection) a strong cotton braid. A cord of this character is used for portable lamps or wherever the cord is subject to much usage. (3) *Heater cord* has an insulation of rubber or of other suitable material over which is a layer of a non-combustible, heat-resisting material, usually woven asbestos. As a mechanical protection, a cotton braid is served over the heat-resisting layer. A number of special types of cord, such as packing-house cord, brewery cord, stage cable and the like, are manufactured. All are described in *Rule* 51.

The sizes of flexible cords vary with the service required. The ordinary drop cord is composed of two conductors, each equivalent to a No. 18, 16 or 14 B. & S. gage solid wire. The smallest flexible cord conductor permitted is No. 18 gage.

32*b*. ¶*I*. FLEXIBLE CORD. Must not, except in street railway property, be used where the difference of potential between the two wires is over 300 volts.

32*c*. ¶*I*. FLEXIBLE CORD. Must not be used as a support for clusters.

Flexible cord should not be used as a support for fixtures because it has not sufficient tensile strength to sustain any great amount of weight.

32*d*. ¶*I*. FLEXIBLE CORD. Must not be used except for pendants, wiring of fixtures, portable lamps or motors, portable heating apparatus or other portable devices.

Long pendants with adjusters should be avoided. The adjusters are liable to injure the insulation. If a long drop-cord

pendant is provided and then an adjuster supplied on it so that its effective length can be shortened the tendency is to use the lamp and cord as a portable lamp. *Pendants of ordinary flexible cord should always hang freely in air.* Flexible cord should never be carried along walls or ceilings either supported by insulators or otherwise and should never be used where No. 14 wire can be made to serve.

The best method of installing a pendant or portable lamp is shown in Fig. 319. Reinforced lamp cord supported at the ceiling with a single-wire cleat and terminating in a properly bushed ⅜-in. socket should be used. Each of the conductors of the cord should be soldered to one of the circuit wires and the joints thoroughly taped.

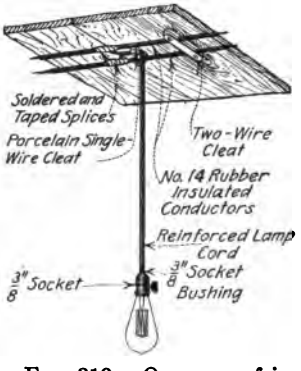


FIG. 319.—One way of installing a pendent lamp. (In some cities the inspection departments require that pendent conductors be supported by rosettes or "cord buttons.")

32*d*. ¶*II*. FLEXIBLE CORD. For all portable work, including those pendants which are liable to be moved about sufficiently to come in contact with surrounding objects, flexible wires and cables especially designed to withstand this severe service must be used.

For portable lamps, that is, for those lamps, the cords of which may not always hang freely in air, reinforced cord should always be used. The reason is that the ordinary flexible cord, Fig. 313, *I*, does not have sufficient insulation and mechanical protection to insure its integrity if it is subjected to the usage ordinarily encountered by a cord which is not always held freely in air.

32*d*. ¶*III*. FLEXIBLE CORD. When necessary to prevent portable lamps from coming in contact with inflammable materials, or to protect them from breakage, they must be surrounded with a substantial guard.

Portable lamps should have protective guards as shown in Fig. 320 to insure against the breakage of the lamp and the fire risk involved thereby. The guard should be of such

construction—should have a close mesh—that things outside of it are not liable to touch the glass bulb of the lamp.

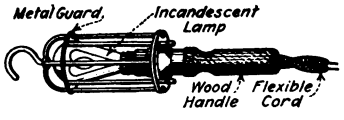


FIG .320.—Metal guard for protection of portable lamp.

32*e*. ¶*I*. FLEXIBLE CORD. Unless provided with *approved* metal armor, must not be used in show windows or in show cases, except that *approved* portable cord may be used for the purpose of supplying current to portable lamps and other devices for exhibition purposes, and flexible cord may be used for chain fixtures.

Metal armored lamp cord should always be used in show windows (Fig. 321) because a large number of fires have been caused through the application of unarmored cord in these locations. Experience has shown that things are hung on lamp cords in windows and even pinned to them. As suggested in the illustration, steel armored flexible cord is attached to the socket by means of a socket adapter and to the rosette or outlet box above with a similar device.

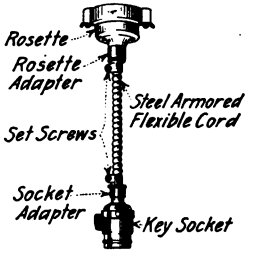


FIG. 321.—Metal-armored lamp cord.

32*f*. ¶*I*. FLEXIBLE CORD. Must be protected by insulating bushings where the cord enters the socket.

Insulating bushings should be used in every socket unless, by reason of the construction of the socket, the conductors entering it are adequately protected from abrasion. Threads in the holes in ordinary sockets present knife-edge corners which will, unless bushings are used, rapidly cut through the insulation on a cord and possibly cause a short-circuit. A composition insulating bushing for a ⅜-in. socket is shown in Fig. 322.

32*g*. ¶*I*. FLEXIBLE CORD. Must be so connected to all fittings that strain is taken from the joints and binding screws.

Cords should be so arranged that they impose no stress upon binding posts or connectors. This provision is usually

satisfied by tying suitable knots, Fig. 323, in the ends of the cord so that any stress imposed will be assumed by the knot bearing against some rugged part of the fittings. The installer should be *certain* that the knot does bear against the porcelain or metal of the fitting and thus relieves the terminals of strain. Special fastening devices for flexible cords are supplied in sockets and fittings of certain makes.

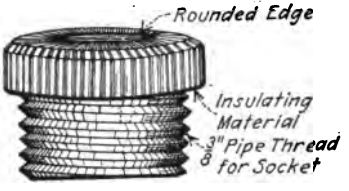


FIG. 322.—38″ insulating socket bushing.

32*h* ¶*I*. FLEXIBLE CORD.

Must where passing through covers of outlet boxes be protected by *approved* bushings especially designed for this purpose. So-called hard rubber or composition bushings threaded into box covers must not be used.

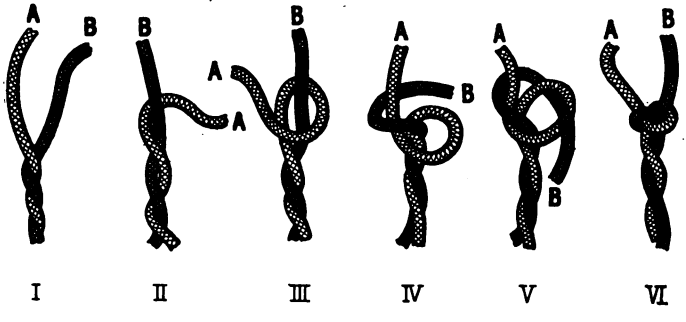


FIG. 323.—Method of tying the so-called "underwriter's knot."

Where a flexible cord passes through an outlet box cover it must be protected against abrasion and contact therewith by a bushing as suggested in Fig. 324. Porcelain bushings, specially made for the purpose and so arranged that they can be substantially fixed in the cover, are the best for this service. However, ordinary composition bushings may be approved for this service by some inspectors if, after the bushing is inserted in the hole, it is heated with a match until plastic and then formed over at the side of the cover so that it cannot

fall out. The metal of an outlet box cover is so thin that the few threads that can be cut in it are not sufficient to hold

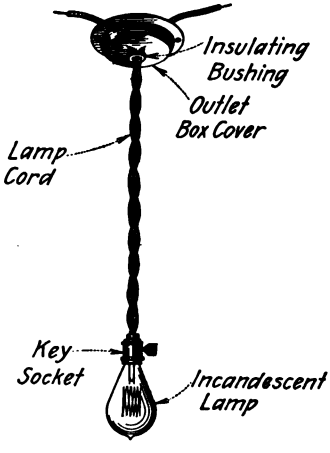


FIG. 324.—Insulating bushing protecting flexible cord where it passes through box cover.

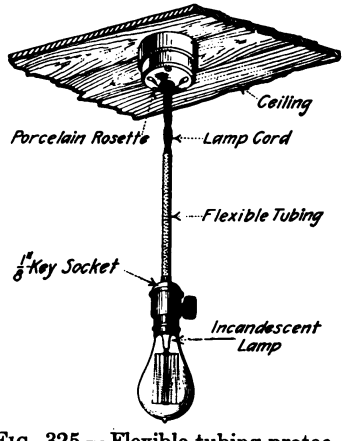


FIG. 325.—Flexible tubing protection for lamp cord.

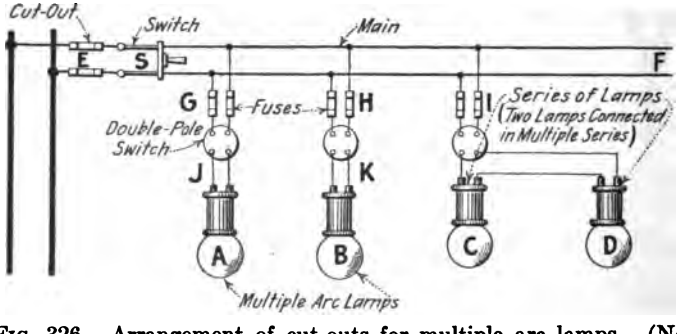


FIG. 326.—Arrangement of cut-outs for multiple arc lamps. (Note that it would be better practice to use instead of the fused switch, *ES*, shown above, one fused at the handle end, so that the blades would be dead when the switch is open. Or, if a separate cut-out and switch are used at *E* and *S*, the switch should, preferably, be reversed from the position shown, see Fig. 201.)

substantially the ordinary composition bushing like that of Fig. 322. Furthermore, these composition bushings are so brittle that they break frequently.

Cord in places where it is liable to become saturated with oil, as in machine shops or factories where the key sockets are operated by men with oily hands, may be protected by flexible tubing as shown in Fig. 325.

33. ARC LAMPS ON CONSTANT-POTENTIAL CIRCUITS.

(For construction of Arc Lamps see No. 74)

Multiple or constant-potential arc lamps operate in multiple as shown in Fig. 326, *A* and *B*, from constant-potential circuits. In some cases groups of lamps are connected two or more in multiple-series across the circuit as indicated at *C* and *D*; this method is used for flame arc lamps or for two lamps in series across a 220-volt circuit.

33*a*. ¶*I*. ARC LAMPS ON CONSTANT-POTENTIAL CIRCUITS. Must have a cut-out (see No. 19*a*) for each lamp or each series of lamps.

Each arc lamp or series of lamps served from a constant-potential circuit must be protected by a fuse, as shown in Fig. 326. The multiple lamps *A* and *B* are protected respectively by the fuses *G* and *H*. The lamps *C* and *D* in multiple-series are protected by the fuses *I*.

33*a*. ¶*II*. ARC LAMPS ON CONSTANT-POTENTIAL CIRCUITS. The branch conductors must have a carrying capacity about fifty per cent in excess of the normal current required by the lamp.

Provision for large starting current must be made in arranging circuits for arc lamps. At the instant at which the lamp starts, the carbons are together and would, if it were not for the fact that there is always a ballasting resistance or its equivalent in series with the arc, create a dead short-circuit. In any case, the initial current is relatively great. Furthermore, the feed mechanisms of these lamps sometimes "stick" and currents of considerable intensity then flow through the lamps for extended periods. Hence, the branch conductors, as for example, *GJ* and *HK* in Fig. 321, should always be capable of carrying a current (in accordance with the values of *Rule* 18) 50 per cent. greater than the normal operating current required by the lamp. If this excess conductor capacity is not provided, there is always a tendency to overfuse

the conductors so that they will pass the starting current. Where a main, for example *EF*, Fig. 326, feeds a number of arc lamps which may all be switched in or out of circuit at the same instant by the switch *S*, the conductors of such a main should preferably also have 50 per cent. excess current-carrying capacity.

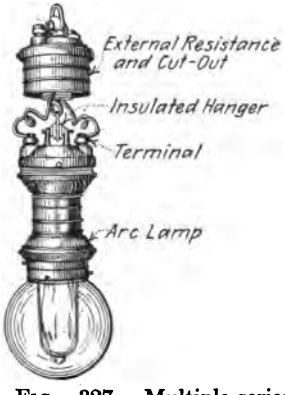


FIG. 327.—Multiple-series arc lamp equipped with external resistance and cut-out.

33*b*. ¶*I*. ARC LAMPS ON CONSTANT-POTENTIAL CIRCUITS. Must only be furnished with such resistances or regulators as are enclosed in non-combustible material, such resistances being treated as sources of heat. Incandescent lamps must not be used for this purpose.

Resistors or regulators for arc lamps are usually mounted within the metal casings of the lamps but frequently they are, as shown in Figs. 327 and 328, arranged as separate units. Where such construction is used, the casing enclosing the resistor must always be so arranged that it is not adjacent to inflammable material. These resistors may under certain conditions become hot enough to originate a fire.

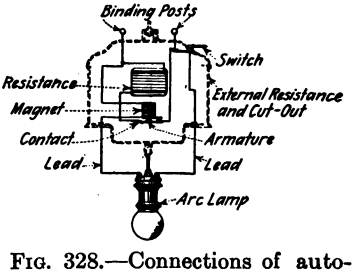


FIG. 328.—Connections of automatic cut-out and resistance for power circuit arc lamp. (Two in series across 220 volts.)

33*c*. ¶*I*. ARC LAMPS ON CONSTANT-POTENTIAL CIRCUITS. Must be supplied with globes and protected by spark arresters and wire netting around the globe, as in the case of series arc lamps (see No. 21).

33*c*. ¶*II*. ARC LAMPS ON CONSTANT-POTENTIAL CIRCUITS. Outside arc lamps must be suspended at least eight feet above sidewalks. Inside arc lamps must be placed out of reach or suitably protected.

To prevent interference by the unauthorized, all arc lamps should be installed high enough above the ground or floor so

that they cannot be reached without a ladder. Experience has shown that observance of this provision may obviate much trouble.

33*d*. ¶*I*. ARC LAMPS ON CONSTANT-POTENTIAL CIRCUITS. Lamps when arranged to be raised and lowered, either for carboning or other purposes, shall be connected up with stranded conductors from the last point of support to the lamp, when such conductor is larger than No. 14 B. & S. gage.

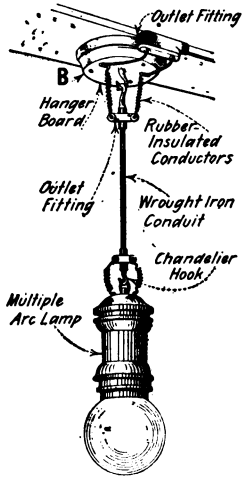


FIG. 329.—Substantial arrangement of an arc lamp.

Stranded leads should be provided for lamps that are to be raised and lowered. That is, the leads should be flexible because leads of solid wire will be strained by the bending action, as the lamp is raised and lowered and as the relatively long loops swing back and forth in the wind, and will ultimately break.

A good method of hanging arc lamps is shown in Fig. 329, wherein the lamp is supported by a conduit hanger through which the conductors pass and which is at each of its ends fitted with an approved outlet fitting. Porcelain hanger blocks, similar to that illustrated in Fig. 330 can frequently be utilized to advantage. These can be procured either with or without fuse receptacles or with or without switches. They provide a very compact rugged arrangement.

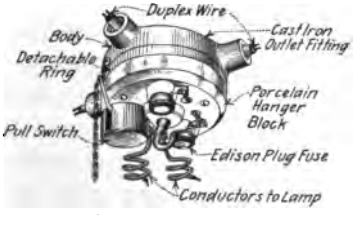


FIG. 330.—Multiple-arc-lamp hanger block arranged on fitting especially designed for exposed conduit wiring.

33*e*. ¶*I*. ARC LAMPS ON CONSTANT-POTENTIAL CIRCUITS. Economy and compensator coils for arc lamps must be mounted on non-combustible, non-absorptive, insulating supports, such as glass or porce-

lain, allowing an air space of at least one inch between frame and support, and must in general be treated as sources of heat.

34. VAPOR LAMPS.

ENCLOSED MERCURY VAPOR LAMPS

Mercury vapor lamps consist (as shown in Fig. 331 and diagrammed in Fig. 332) of a glass tube which contains a vapor of mercury. When an electric current is forced through this vapor it becomes luminous, emitting a light of a greenish cast. To start the tube it is necessary to tilt it permitting the

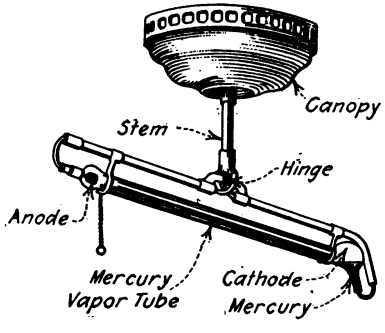


FIG. 331.—Single-tube mercury vapor lamp.

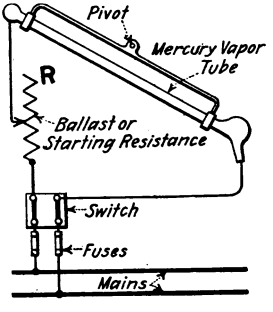


FIG. 332.—Elementary circuit diagram of wiring for a single-tube mercury vapor lamp.

mercury in the cathode bulb to bridge between the cathode and the anode. A resistance, *R*, Fig. 332, or its equivalent, is provided to limit this starting current and to vary current taken by the tube. Figs. 331 and 332 illustrate but one of many possible forms. Where great intensity of light is required a number of tubes are arranged in one bank to form a lighting unit.

34*a*. ¶*I*. MERCURY VAPOR LAMPS. Must have cut-out for each lamp or series of lamps except when contained in single frame and lighted by a single operation, in which case not more than five lamps should be dependent upon single cut-out.

In wiring for mercury vapor lamps each tube or each series of tubes, when a number are mounted in a single frame, should,

as shown in Fig. 332, be protected by fuses. A double-pole switch should be provided. In no case should more than five tubes be fed through a set of fuses.

34b. ¶*I*. MERCURY VAPOR LAMPS. Must only be furnished with such resistances or regulators as are enclosed in non-combustible cases, such resistances to be treated as sources of heat. In locations where these resistances or regulators are subject to flyings of lint or combustible material, all openings through cases must be protected by fine wire gauze.

HIGH-POTENTIAL VACUUM TUBE SYSTEMS

The Moore tube system is a high-voltage vacuum tube lighting system which has been used to some extent, particu-

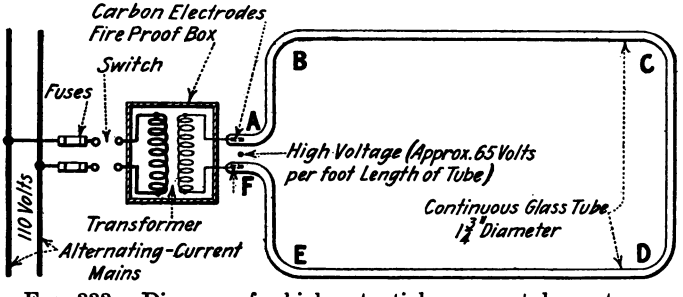


FIG. 333.—Diagram of a high-potential vacuum tube system.

larly for advertising. It is illustrated diagrammatically in Fig. 333. A continuous clear-glass tube *ABCDEF*, usually 1¾ in. in diameter, is arranged around the ceiling of the room to be illuminated. The tube may have a length of only a few feet, or it may be of a length as great as 200 ft. The tube has within it rarefied air or a non-metallic gas. Now, if a high voltage is impressed on the ends of the tube as at *A* and *F*, Fig. 333, the rarefied gas within the tube will glow and give forth light. Where the tube has a rarefied air filling, the light is pink, but lights of other colors can be produced by using different gases within it. The voltage required across *AF* for a tube 100 ft. long is 7,150 volts. For a 150-ft. tube a pressure of 9,750 volts is required and for a 200-ft. tube 12,250 volts pressure is required. These tube systems operate satisfactorily only on alternating current because the high voltage

required cannot be obtained readily with direct current. The high voltage impressed across the tube terminals *AF* is developed with a step-up transformer having a low-tension voltage of 110 or 220.

34*c*. ¶*I*. VACUUM TUBE SYSTEMS. The tube must be so installed as to be free from mechanical injury or liability to contact with inflammable material.

34*d*. ¶*I*. VACUUM TUBE SYSTEMS. High-potential coils and regulating apparatus must be installed in *approved* steel cabinet not less than one-tenth inch in thickness; same to be well ventilated in such a manner as to prevent the escape of any flame or sparks, in case of burnout in the various coils. All apparatus in this box must be mounted on slate base and the enclosing case positively grounded. Supplying conductors leading into this high-potential case to be installed in accordance with the standard requirements governing low-potential systems, where such wires do not carry a potential of over 300 volts.

The enclosure for the step-up transformer used with the Moore vacuum tube system is, as provided by the manufacturers, of metal and, therefore, non-combustible. The auxiliary apparatus otherwise conforms to the requirements outlined by the CODE.

In wiring for a high-potential vacuum tube system the circuit may be arranged about as shown in Fig. 333. Each tube should be controlled by a double-pole switch and protected by a cut-out.

35. GAS FILLED INCANDESCENT LAMPS.

Gas-filled incandescent lamps, Fig. 334, are tungsten lamps the bulbs of which contain an inert gas. The filaments of ordinary or "vacuum" incandescent lamps operate in a vacuum. It is possible to operate the tungsten wire filaments at higher temperatures in the gas-filled bulbs. The presence of the gas retards the evaporation of the filament. Nitrogen has been used for the inert gas; hence the lamps are often designated as nitrogen-filled lamps. Because of their high operating temperature the gas-filled lamps are considerably more efficient than the vacuum lamps. They are sometimes called *Mazda Type C* lamps to distinguish them from the vacuum tungsten lamps which are called *Mazda Type B*. It

should be remembered then that the filaments of gas-filled tungsten lamps operate at exceedingly high temperatures and in wiring for them this feature must be considered. Obviously it becomes of importance only at locations in or near the fixtures containing the lamps. The bulbs of these lamps may become very hot.

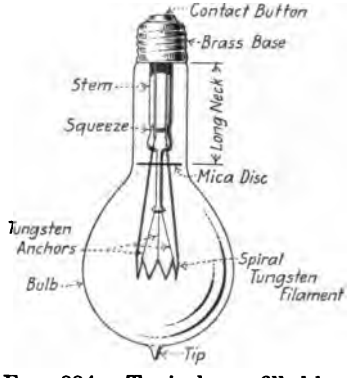


FIG. 334.—Typical gas-filled-lamp construction.

35a. ¶1. GAS FILLED LAMPS. Must be so grouped that not more than 660 watts (nor more than 16 sockets or receptacles) are to be dependent on one cutout except that in cases where wiring equal in size to No. 14 B. & S. gage is carried directly into keyless sockets or receptacles, the location of which is such as to render unlikely the attachment of flexible cords thereto, the circuits may be so arranged that not more than 1,320 watts (or 32 sockets or receptacles) will be dependent on the final cutout. Where a single socket or receptacle is used on a circuit the limitation of watts permissible on the final cutout shall be the maximum capacity for which such socket or receptacle is approved.

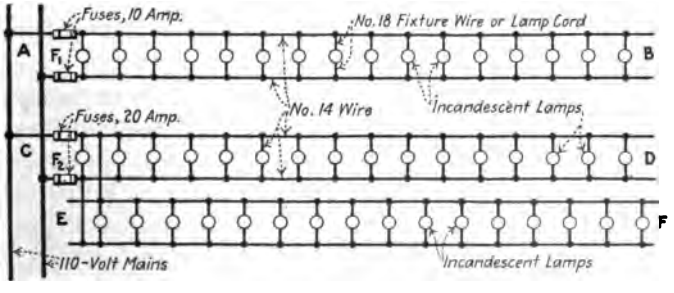


FIG. 335.—Illustrating the permissible loadings of gas-filled incandescent lamp circuits.

The permissible load on a gas-filled incandescent lamp circuit is determined in a measure by the sizes of the conductors in the circuit. If any of the lamps on a circuit (*AB*, Fig. 335) is served through conductors smaller than No. 14

that is, through No. 18 fixture wire or lamp cord, then the maximum load that should be fed through a single set of fuses F_1 is 660 watts. Not more than 16 sockets should be connected to such a circuit. The fuses (*Rule* 23*e*, ¶*IV*) may be of 10-amp. capacity as illustrated. If the conductor connected to the branch circuit is in no case smaller than No. 14, then, as shown at *CDEF*, a load of 1,320 watts or 32 sockets or receptacles may be served through one cut-out, which may, on a 110-volt circuit, be protected by a 20-amp. fuse, F_2, in accordance with the provision of *Rule* 23*d*, ¶*VII*.

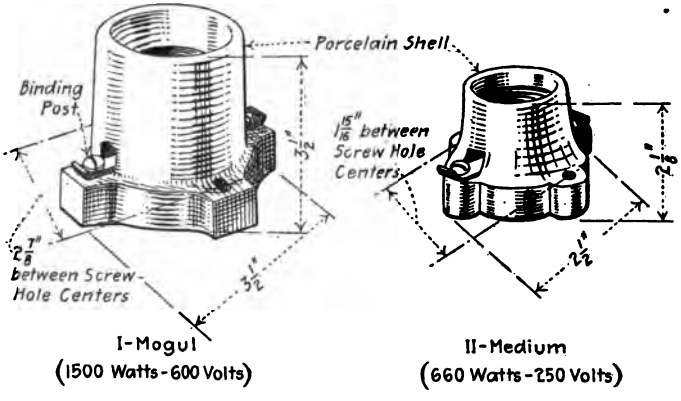


FIG. 336.—Illustrating comparative difference in size between "mogul" and "medium" receptacles.

The permissible load on a single socket or receptacle through which a gas-filled lamp is served is determined by the size of the socket or receptacle. A keyless socket or receptacle of the Mogul type (Fig. 336, *I*) has, except as noted below, (*Rule* 35*c*, ¶*I*) a capacity of 1,500 watts on either 250 or 600 volts. A "medium" keyless receptacle or socket (Fig. 336, *II*) has ordinarily a capacity of 660 watts on either 250 or 600 volts. Key sockets have ordinarily a capacity of 250 watts or 660 watts on 250 volts. Those for 660 watts are of more rugged construction than the smaller ones. However (*Rule* 35*c*), medium-base sockets or receptacles should not be used for carrying gas-filled lamps of capacities exceeding 200 watts. Key-switch Mogul sockets should not be used. It is better

to use a socket of the keyless type and control it with a separate switch.

35b. ¶I. GAS FILLED LAMPS. Must not be used in show windows or in other locations where inflammable material is liable to come in contact with lamp equipment except where used in connection with *approved* fixtures where temperature of any exposed portion of same does not exceed 200 degrees Fahr. (93 degrees Centigrade).

Gas-filled lamp fixtures for interior service are shown in Figs. 337 and 338. These illustrations indicate typical construction but fixtures of many different types which will give satisfactory service are available. Note that the important feature in each of the designs shown is that the gas-filled lamp (which may become very hot in service) is supported entirely clear of any combustible material and it is so arranged that the air may

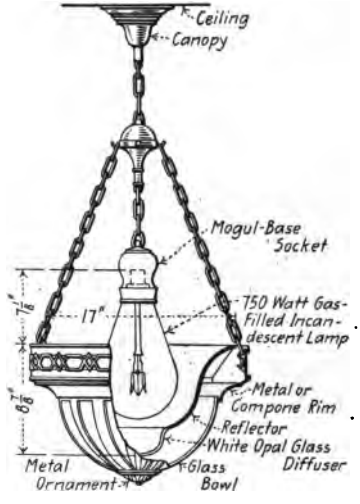


FIG. 337.—Semi-indirect lighting fixture for gas-filled incandescent lamp. (National *X*-ray reflector company.)

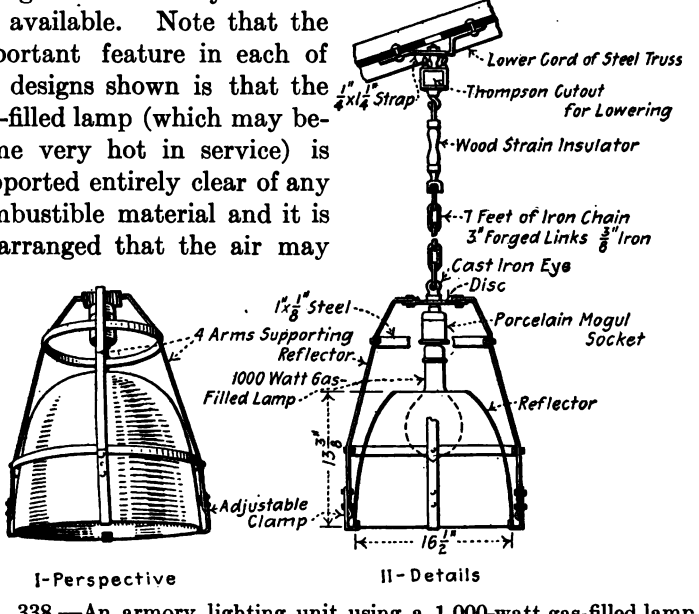


FIG. 338.—An armory lighting unit using a 1,000-watt gas-filled lamp

circulate about it freely and thus tend to keep the lamp and the fixture cool. Fig. 339 indicates how an arc lamp casing may be adapted into a container for a gas-filled lamp. The arrangement shown is that of the *Metropolitan Engineering Company*, New York. The long cylindrical portion of an arc lamp casing, when it is arranged as shown, constitutes a chimney which is very effective in creating a draft. Cool air is drawn in at the hole at the bottom of the globe, becomes heated, rises in the flue and flows out at *A* and *A*. It also induces cool air to enter at *B* and *B* above the top of the globe. This cool air impinges on what would ordinarily be the hottest part of the lamp. It is claimed that the system of circulation illustrated maintains the temperature of the lamp as low as if it were supported in air without any globe or fixture associated with it.

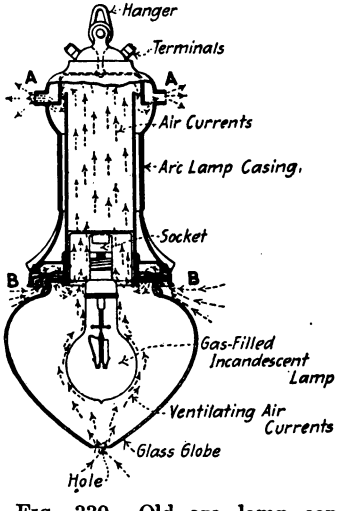


FIG. 339.—Old arc lamp converted into a container for a gas-filled incandescent lamp.

35c. ¶*I*. GAS FILLED LAMPS. Must not be used in connection with medium-base sockets or receptacles if of above 200 watts nominal capacity nor with Mogul base sockets or receptacles if of above 1,500 watts capacity. If of above 100 watts, must not, if provided with a shade, reflector, fixture or other enclosure above the socket, be used in either medium or Mogul base types of sockets or receptacles having fibre or paper linings.

The dimensions of medium bases and Mogul bases for incandescent lamps are indicated, actual size, in Fig. 340. Although medium-base sockets are ordinarily given a rating of 250 watts (*Rule* 72*a*) they should not be used for feeding a gas-filled lamp of a greater capacity than 200 watts. Mogul-base sockets may serve gas-filled lamps of ratings up to and including 1,500 watts. Insulating linings of combustible

material are not permitted in sockets or receptacles for gas-filled lamps if the lamp has a rating of over 100 watts and the socket is equipped with a shade, reflector or similar auxiliary that might prevent free circulation of air. Experience has shown that paper or fiber linings in sockets carrying large gas-filled lamps may, if air circulation is retarded, be "cooked" and thereby rendered useless.

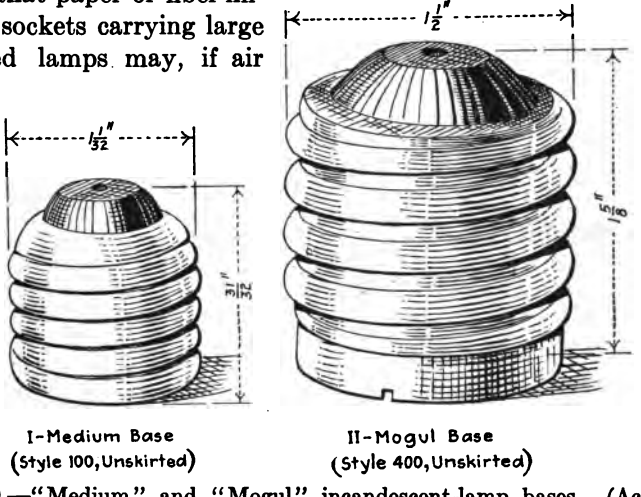


FIG. 340.—"Medium" and "Mogul" incandescent-lamp bases. (Actual size.)

35*d*. ¶*I*. GAS FILLED LAMPS. Fixtures within buildings must be wired with conductors of *approved* slow-burning or asbestos covering where the temperature to which wire is subjected at any point exceeds 120 degrees Fahr. (49 degrees Centigrade). Where fixtures are placed outside of buildings *approved* rubber insulated wire is required.

Gas-filled lamp fixtures for outdoor service are illustrated in Figs. 341 and 342. That of Fig. 341 is typical of the fixtures used for store-front and other lighting of similar character. Note from the sectional elevation *II* that provision for effective air circulation, particularly around the base and neck of the lamp where the temperature tends to be highest, has been provided. Fig. 342 illustrates the construction of the lighting units furnished by the *National X-ray Reflector Company* for the "flood-lighting" illumination of the Woolworth Building

tower, New York City. The problem in this case was to design a fixture that could be tilted or placed at any angle, which would be thoroughly ventilated and which, at the same time,

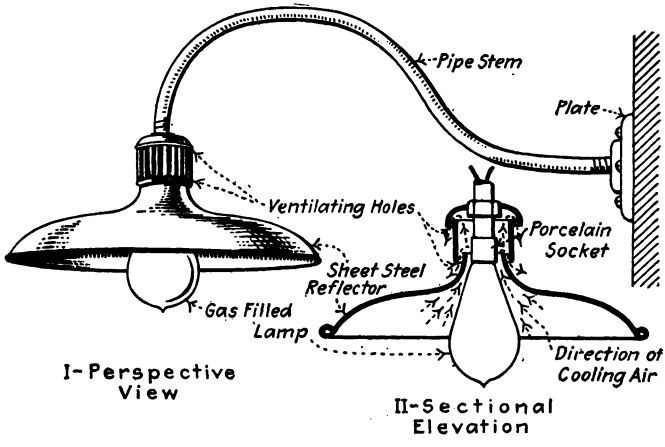


FIG. 341.—Typical gas-filled lamp fixture for outdoor service.

would exclude rain and moisture from the interior. The sectional elevation of *II* indicates how the problem was solved.

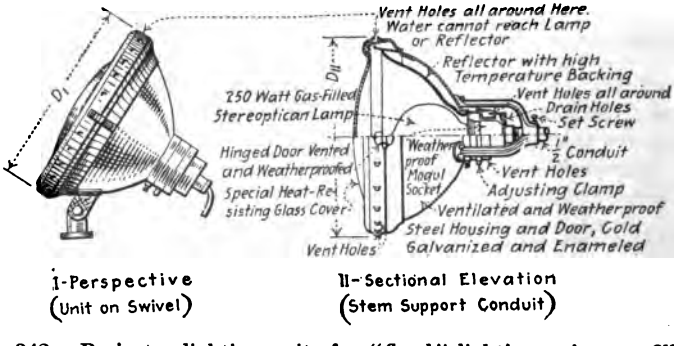


FIG. 342.—Projector lighting units for "flood" lighting, using gas-filled lamps.

Lips or deflecting rings are provided so that if rain does enter the air-vent holes at the top or sides, it will flow around and drip out of the vent holes at the bottom.

36. TRANSFORMERS.

(*See also Nos.* 11, 14, 15, and 45)

(*For construction of Transformers see No.* 81)

OIL TRANSFORMERS

36*a*. ¶*I*. OIL TRANSFORMERS. Must not be placed inside of any building except central stations and sub-stations, unless by special permission.

The reason why oil-cooled transformers should not be installed within buildings is that they always constitute a source of considerable fire hazard. The oil is combustible as are the oil-saturated insulating materials on the windings. The oil may become ignited due to a continuous overload on the transformer or to a short-circuit or ground within it. Lightning may "burnout" transformers. However, there is usually little difficulty in obtaining permission from an *Inspection Department* for the installation of *low-tension* transformers within buildings if the winding and oil are sealed within an oil-tight, iron case. Many such transformers are installed within buildings in practice.

AIR COOLED TRANSFORMERS

The following sections do not apply to apparatus or fittings, the operation of which depends either wholly or in part upon special transformers embodied in the devices, but all such apparatus or fittings must be submitted for special examination and approval before being used.

36*b*. ¶*I*. AIR COOLED TRANSFORMERS. Must not be placed inside of any building excepting central stations or sub-stations, if the highest voltage of either primary or secondary exceeds 550 volts.

36*c*. ¶*I*. AIR COOLED TRANSFORMERS. Must, with the exception of bell ringing and other signaling transformers, be so mounted that the case shall be at a distance of at least one foot from combustible material or separated therefrom by non-combustible, non-absorptive, insulating material, such as slate, marble or soapstone. This will require the use of a slab or panel somewhat larger than the transformer.

37. DECORATIVE LIGHTING SYSTEMS.

37. ¶*I*. DECORATIVE LIGHTING SYSTEMS. Special permission may be given in writing for the temporary installation of *approved* Systems of Decorative Lighting, provided the difference of potential between the wires of any circuit shall not be over 150 volts and also pro-

vided the difference of potential between the wires of any circuit shall not be over 150 volts and also provided that no group of lamps requiring more than 1,320 watts shall be dependent on one cut-out.

Sockets used for decorative or temporary lighting systems are shown in Fig. 343. In that of *I*, pointed contactors are provided which will penetrate the insulation on No. 12 or 14 wire and connect with the copper conductor when the screws are tightened. Obviously with this type it is not necessary to "skin" the wire. Only stranded wire should be used in

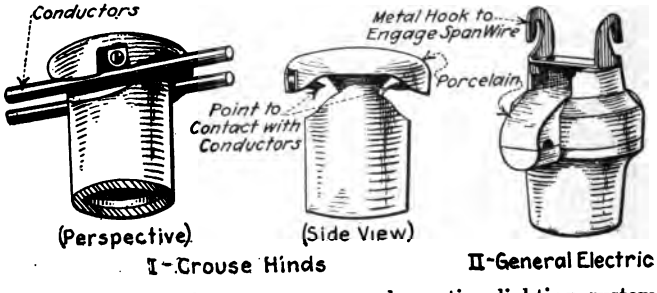


FIG. 343.—Sockets for temporary or decorative lighting systems.

this work because the sharp points may cut a solid conductor or nick it so badly that it will break. Metal hooks to engage with a non-current-carrying span wire are provided on the socket shown at *II*. Only *approved* fittings should be used in these "decorative" lighting systems.

38. THEATRE AND MOVING PICTURE ESTABLISHMENT WIRING.

Absolute reliability and safety are the features that dictate theater-wiring requirements. Because of the large amount of capital invested in theaters and because of the fact that large numbers of people assemble in them, every precaution should be taken to prevent the possibility of a fire due to an electrical or any other origin. For these reasons, only the best methods of wiring should be used. It follows that all conductors should, where possible, be carried either in rigid or flexible conduit, in metal molding, or should be armored cable. It is possible to wire the auditorium and all parts of the theater,

except the stage, by one of these methods. However, on the stage, as will be described, many portable electrical devices are used which can be satisfactorily fed only through flexible conductors, the rubber-and-braid insulation on which provide the only protection. These conductors that are not protected by metal should be used only where it is essential that conductors be flexible.

The life-hazard feature is of as great or even possibly of greater importance than that of fire hazard in theater electrical construction. That is, precautions must be taken to prevent the starting of small fires or flashes which, while they might do no property damage, could create a panic and thereby result in loss of life.

38. ¶*I*. THEATRE WIRING. All wiring, apparatus, etc., not specifically covered by special rules herein given, must conform to the general requirements of this Code, and the term "theatre" shall mean a building, or that part of a building regularly or frequently used for dramatic, operatic, moving picture or other performances or shows or which has a stage for such performances used with scenery or other stage appliances.

a. SERVICES

38*a*. ¶*I*. THEATRE WIRING—SERVICE. Where supply may be obtained from two separate street mains, two separate and distinct services must be installed, one service to be of sufficient capacity to supply current for the entire equipment of theatre, while the other service must be at least of sufficient capacity to supply current for all emergency lights. Where supply cannot be obtained from two separate sources, the feed for emergency lights must be taken from a point on the street side of main service fuses. By "emergency lights" are meant exit lights and all lights in lobbies, stairways, corridors, and other portions of theatre to which the public have access, which are normally kept lighted during the performance.

There should be at least two services for every theater. The auditorium and stage-lighting circuits, that is, the general circuits, may be fed from one of these services, while the other service should feed exclusively the "emergency" lights as shown in Figs. 344 and 345. The emergency lights comprise all of the lights that illuminate the exit doors and the passages which would be used by people in passing from the theater. The idea is to insure, in so far as possible, that there

will always be sufficient light even in case of fire or other accident, and even if the general lighting system is inoperative, to

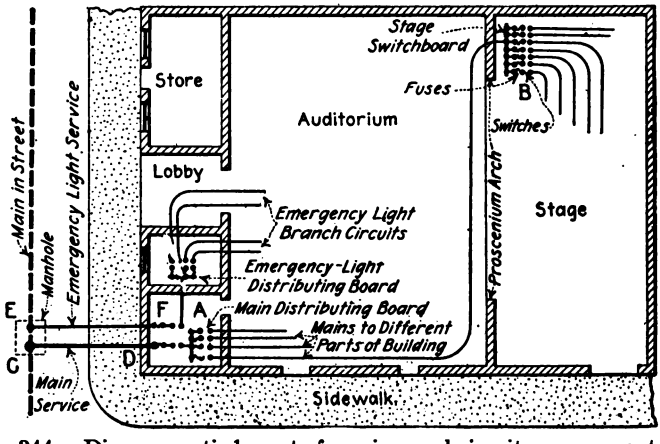


FIG. 344.—Diagrammatic layout of services and circuit arrangements for a theater.

(NOTE.—Contrary to the arrangement shown above, it is considered best practice to have only the main switch control the exit lights so that when the main switch for the emergency lights is closed, the exit lights will remain illuminated and can not be extinguished by a separate switch.)

permit the audience to pass from the theater and to provide firemen sufficient light to work by. In Fig. 344, the general

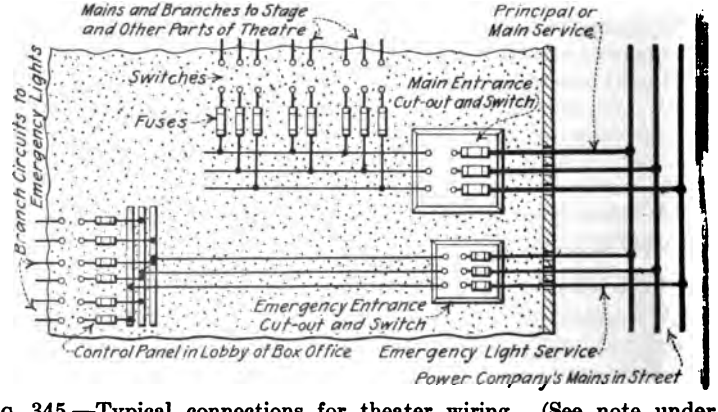


FIG. 345.—Typical connections for theater wiring. (See note under Fig. 344.)

lighting service *CD* runs from the manhole underground to a main distributing board. From there the sub-feeders radiate

to the different electrical loads, one of them feeding the stage switchboard at *B*. The emergency-light service *EF* is entirely independent of *CD*. It also passes underground from the street manhole to its own service switch and fuse and thence to the emergency-light distributing board, which should be (*Rule* 38*t*, ¶*III*) located in the lobby, box office, or other convenient point in the front of the house.

If two different mains are available in the street, a separate service should be taken from each of these, one for the emergency and one for the general lighting, in preference to having both of them feed from the same main, as shown in Fig. 344. In any case, the two services into the building should be entirely independent, even if they must feed from the same street main. It is desirable that each of these services be routed by different courses from the manhole or pole, to the service switch in the theater. The emergency-lighting circuits and the general-lighting circuits should in no way be interconnected in the theater. Fig. 345 illustrates diagrammatically the above discussed principles.

38*a*. ¶*II*. THEATER WIRING—SERVICE. Where source of supply is an isolated plant within same building, an auxiliary service of at least sufficient capacity to supply all emergency lights must be installed from some outside source, or a suitable storage battery within the premises may be considered the equivalent of such service.

If the theater lighting is furnished by an isolated plant, an auxiliary source of e.m.f. should be provided for the emergency lights so that if the isolated plant becomes inoperative at the time of a fire the emergency lights can be served from the auxiliary source. For example, a storage battery may be used as suggested in Fig. 346. The storage battery should preferably be kept charged at all times and the emergency lights should be fed from it. However, if desir-

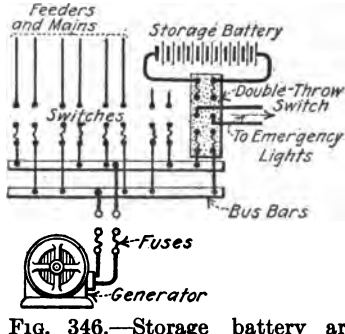


FIG. 346.—Storage battery arranged for emergency service.

able, these lights may be served from the generator bus bars by throwing the double-throw switch.

An auxiliary-fuse switch, Fig. 347, is often inserted in the sub-feeder which serves the auditorium lights. This is merely a double-throw fused switch. If one set of the fuses "blows" the auditorium can be relighted quickly by merely throwing the switch to the reverse position.

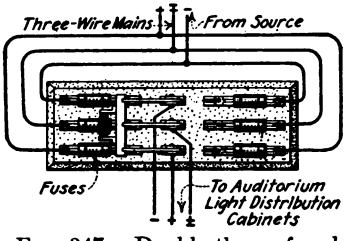


FIG. 347.—Double-throw fused switch cut in auditorium-light circuit.

b. STAGE

38*b*. ¶*1*. THEATER WIRING—STAGE. All permanent construction on stage side of proscenium wall, except as hereinafter provided, must be *approved* conduit or armored cable.

The stage of a theater is a particularly hazardous place because of the large amount of combustile material that is always present and because of the fact that it is necessary to use considerable stage cable and other electrical conductors, not protected by metal casings, to produce the electrical and lighting effects that are necessary. Temporary connections are, of necessity, frequently utilized. Hence, the most stringent rules govern the construction and installation of stage electrical apparatus. The conductors should always where possible, be enclosed in iron-clad runways and cabinets—except where other construction is essential because of practical considerations.

c. SWITCHBOARDS

38*c*. 1. ¶*1*. THEATER WIRING—SWITCHBOARDS. Must be made of non-combustible, non-absorptive insulating material, and where accessible from stage level must be protected by a suitable guard-rail to prevent accidental contact with live parts on the board and comply with the requirements of Rule 3.

Switchboards for theaters should satisfy all of the general requirements outlined in *Rule* 3 for all switchboards. In addition there are certain special requirements governing the construction and installation of stage switchboards (Fig. 348). Frequently there are two switchboards in a theater, the dis-

tributing switchboard, *A*, Fig. 344, and the stage switchboard, *B*. In addition to these switchboards there are numerous distribution cabinets. A stage switchboard is usually installed at a rather hazardous location (*B*, Fig. 344) on the stage at one side or the other of the proscenium arch.

A stage switchboard should preferably be located above the stage level, so that it is necessary to mount a couple of steps to

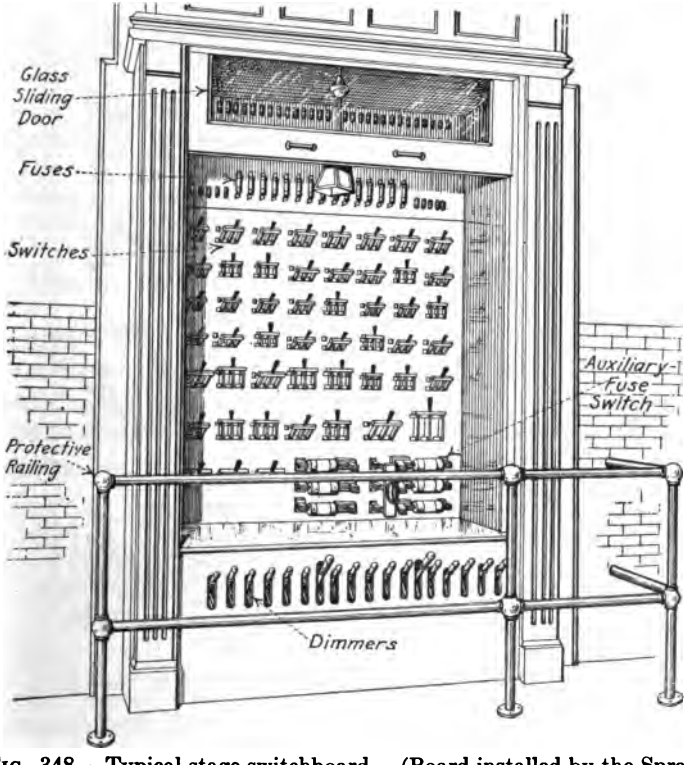


FIG. 348.—Typical stage switchboard. (Board installed by the Sprague Electrical Company in the Gayety theater, Brooklyn, N. Y.)

get to it. The reason for this is that performers, who are frequently dressed in flowing garments or in costumes that are composed partially of conducting materials such as metal and tinsel, are constantly passing the board. If the board is close enough, these conductors in the costumes, unless the board is

protected, may contact with the switches on the board and cause short-circuits. Whether or not the switchboard is elevated above the stage level, a railing should always be installed in front of it, as suggested in Fig. 348. It is good

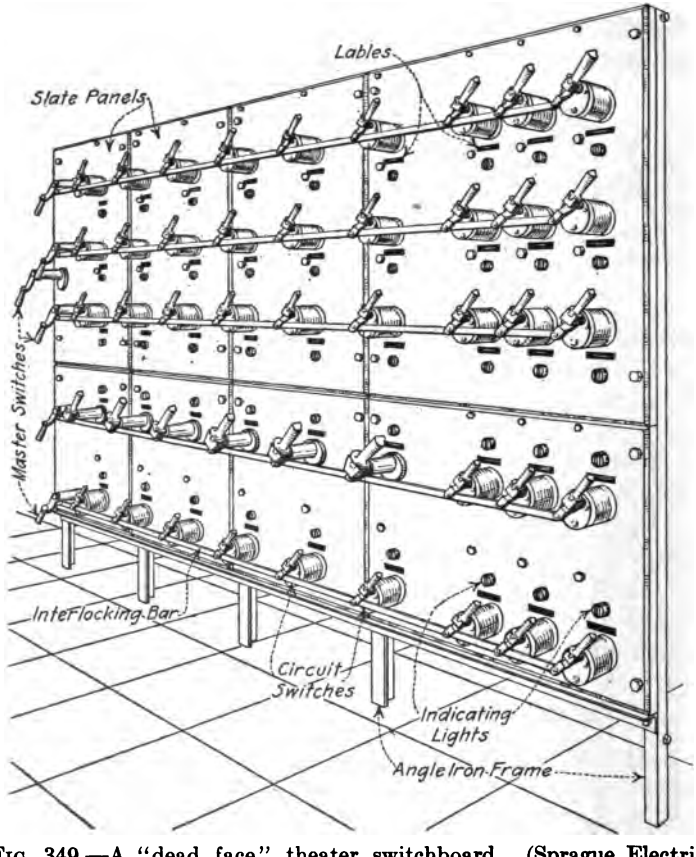


FIG. 349.—A "dead face" theater switchboard. (Sprague Electric Company, Weber and Fields Music Hall, Roof Garden, New York.)

construction, where feasible, to arrange a wire-grating enclosure entirely around the switchboard. Stage switchboards are made which have no live parts on their fronts (Fig. 349). These, of course, are desirable but are more expensive than those of the ordinary type shown in Fig. 348.

38c. 2. ¶*I*. THEATER WIRING—SWITCHBOARDS. **Dimmers must be dead when the switch controlling circuit of which dimmer forms a part is open.**

A dimmer (Figs. 350 and 351) is merely a rheostat cut in series between the source of supply and a group of stage lighting incandescent lamps, used for decreasing the intensity of

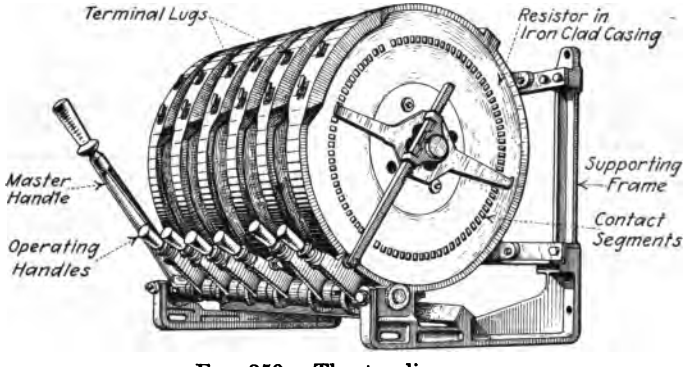


FIG. 350.—Theater dimmer.

the illumination where it is desired to produce "evening" or "dark" effects.

Dimmer circuits must always be fed through double-pole switches as suggested in Fig. 351, so that when the switch

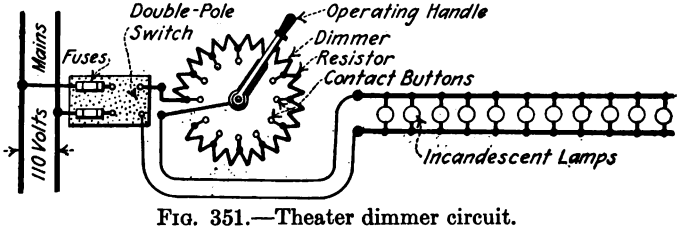


FIG. 351.—Theater dimmer circuit.

is opened, the dimmer will be absolutely "dead." This requirement follows, of necessity, for all dimmers controlling circuits of capacities exceeding 660 watts, because of the provisions of *Rule* 24c, ¶*I*, which requires that all incandescent-lighting circuits serving loads in excess of this capacity be fed through double-pole switches. Dimmers are usually incorporated in the stage switchboard as shown in Fig. 348.

d. FOOTLIGHTS

38*d.* ¶*I.* THEATER WIRING—FOOTLIGHTS. Must be wired in *approved* conduit or armored cable, each lamp receptacle being enclosed within an *approved* outlet box, or the lamp receptacles may be mounted in an iron or steel box, metal to be of a thickness not less than No. 20 U. S. Sheet Metal gage treated to prevent oxidation, so constructed as to enclose all the wires and providing at least one-half inch separation between the metal of the box and receptacle terminals. Wires to be soldered to lugs of receptacles.

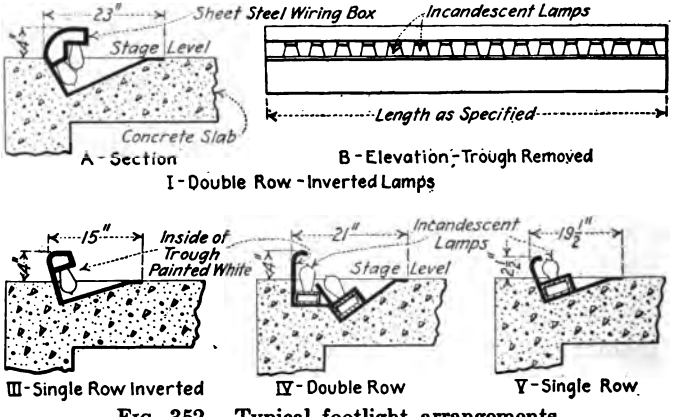


FIG. 352.—Typical footlight arrangements.

The desideratum in stage lighting is usually to eliminate pronounced shadows. The footlights, border lights, and other

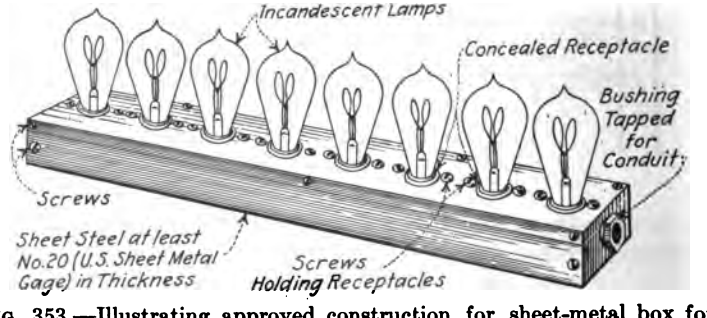


FIG. 353.—Illustrating approved construction for sheet-metal box for containing footlight receptacles and conductors.

lighting devices to be hereinafter described, are, as a rule, utilized to produce this general effect.

Footlight construction is shown in Figs. 352, 353 and 354. There are a number of different methods of making footlights, but those illustrated are typical. In modern theaters, the sheet-iron footlight trough comprising the reflector and wiring box, rests but is not fastened in a semicircular groove (Fig. 352) in the concrete floor at the front of the stage. The entire footlight trough can be removed whenever necessary for cleaning or for any other purpose. Frequently a cast-iron "nose" is provided which rises from the front over that part of the footlight reflector which extends above the floor. The nose protects the projecting portion from mechanical injury.

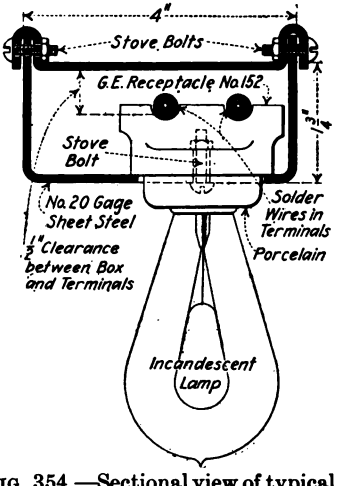


FIG. 354.—Sectional view of typical box.

All footlight wiring must be enclosed in a metal casing or in a box which may be constructed about as detailed in Fig. 353. Fig. 354 shows a section through a wiring box of this character. The box of Fig. 354 was designed for use in border-light wiring, but the general construction indicated could be used for footlights. Footlight wiring may be, but seldom is, carried in wrought-iron conduit.

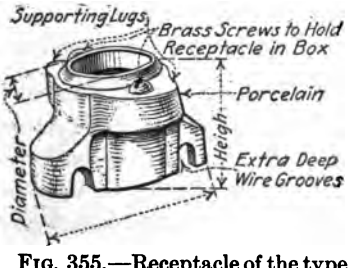


FIG. 355.—Receptacle of the type used in wiring footlights, borders and side lights (G. E. No. 152).

Receptacles for foot, border, proscenium, side and strip lights are usually of the general form detailed in Fig. 355. They are supported in the wiring boxes as indicated in Fig. 354, each receptacle being held therein by two stove bolts. The conductors should always be soldered in the receptacle terminals to minimize the likelihood of their becoming loose and making trouble.

38*d*. ¶*II*. THEATER WIRING—FOOTLIGHTS. Must be so wired that no set of lamps requiring more than 1,320 watts nor more than 32 receptacles shall be dependent upon one cut-out.

BORDERS AND PROSCENIUM SIDELIGHTS

38*e*. 1. ¶*I*. THEATER WIRING—BORDERS AND PROSCENIUM. Must be constructed of steel of a thickness not less than No. 20 U. S. Sheet Metal gage, treated to prevent oxidation, be suitably stayed and supported, and so designed that flanges of reflectors will protect lamps.

Border lights are arranged to hang horizontally suspended from above and throw their light downwardly. They are

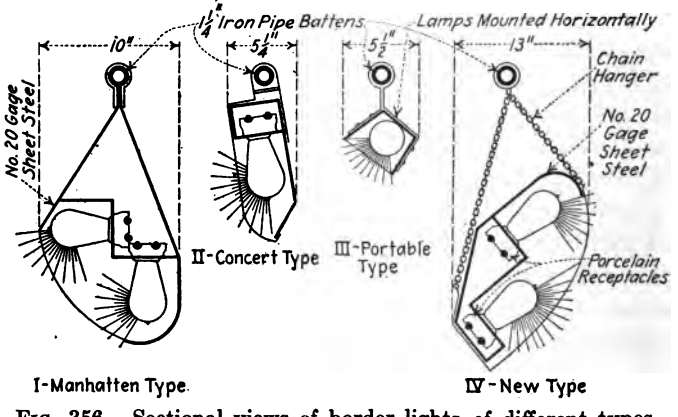


FIG. 356.—Sectional views of border lights of different types.

concealed by the scenery borders. Their general construction is the same as that of footlights. All of the conductors must be enclosed in metal casings. Fig. 356 shows sectional views of border lights of different types that may be used to satisfy different requirements. The border lights which are suspended by chains can be adjusted as to position by changing the suspension hook from link to link in the chain which supports the trough. Thus the trough may be hung in a position tilted more or less from the vertical, as conditions require.

Proscenium lights are usually arranged about as diagrammed in Fig. 357, being set vertically along at the inner edge of the proscenium arch sides and are concealed from the

view of the audience. They are of the same general construction as footlights and border lights, their conductors being enclosed in wiring boxes which also protect the major portions of the lamp receptacles.

38*e*. 2. ¶*I*. THEATER WIRING —BORDERS AND PROSCENIUM. Must be so wired that no set of lamps requiring more than 1,320 watts nor more than 32 receptacles shall be dependent upon one cut-out.

38*e*. 3. ¶*I*. THEATER WIRING —BORDERS AND PROSCENIUM. Must be wired in *approved* conduit or armored cable, each lamp receptacle to be enclosed within an approved outlet box, or the lamp receptacles may be mounted in an iron or steel box, metal to be of a thickness not less than No. 20 U. S. Sheet Metal gage treated to prevent oxidation, so constructed as to enclose all wires. Wires to be soldered to lugs of receptacles.

38*e*. 4. ¶*I*. THEATER WIRING —BORDERS AND PROSCENIUM. Must be provided with suitable guards to prevent scenery or other combustible material coming in contact with lamps.

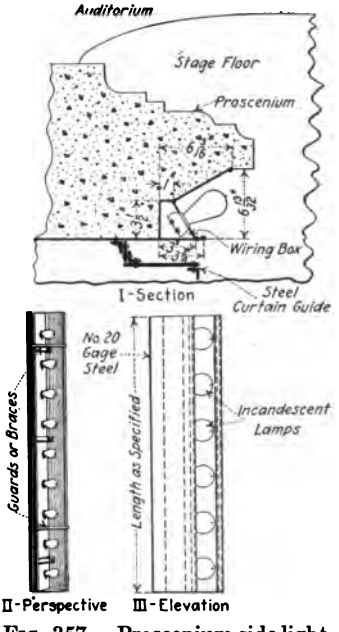


FIG. 357.—Proscenium side light.

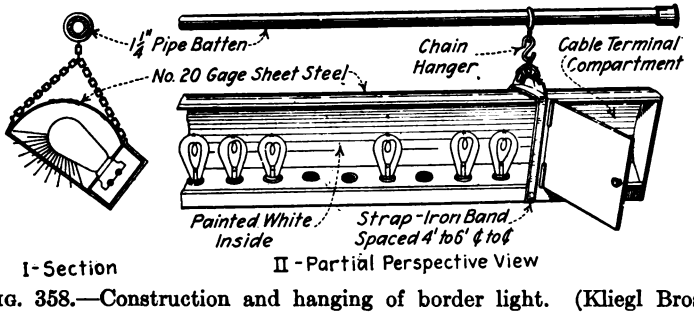


FIG. 358.—Construction and hanging of border light. (Kliegl Bros.)

Guards to prevent combustible materials contacting with border and proscenium-light lamps should be provided as

suggested for border lights in Figs. 358 and 359 and for proscenium lights in Fig. 357. For border lights these guards usually comprise strap iron bands spaced 4 to 6 ft. center to center along the entire length of the border light. They are riveted to the reflector portion of the border-light trough and pass entirely around it. They prevent flopping scenery from touching the lamps. Wire netting, which was once used extensively for the fronts of border lights to prevent the scenery from touching them is now seldom applied, it having been found that the strap iron bands just described provide adequate protection. Proscenium lamp guards are similar, (Fig. 357), to those used for border lights and furthermore, the construction of the proscenium lamp trough should be such that the lamps in it are protected in a measure, at least, from mechanical injury.

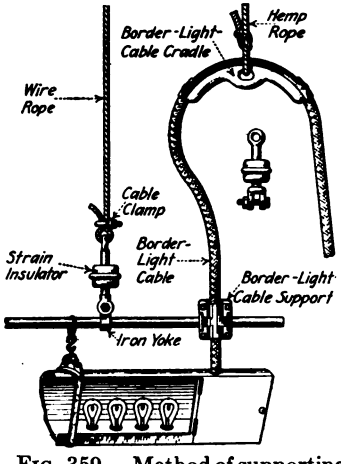


FIG. 359.—Method of supporting border-light cable at border light. (Kliegl Bros.)

38e. 5. ¶*I*. THEATER WIRING —BORDERS AND PROSCENIUM. Cables for borders must be of *approved* type and suitably supported; conduit construction must be used from switchboard to point where cables must be flexible to permit of the raising and lowering of border.

Cables for border lights may frequently comprise many conductors, particularly where the stage is large, requiring long border lights. Ordinarily incandescent lamps of four different colors, white, amber, red and blue, are used in border lights. Frequently also there are more white lamps than there are lamps of any other color and these white lamps are further subdivided into groups so that different intensities of "white" illumination may be obtained. These cables are made to special order in practically every case, because different conditions must be satisfied in nearly every installation. They should be constructed in accordance with the specifica-

tions of *Rule* 51, *Table Classification T*, and items *g* and *h*. One method of supporting a border-light cable is detailed in Fig. 359. The cables should be made long enough so that the border-light trough can be lowered to within about 5 ft. of the floor, thereby permitting the replacement of lamps. Because of the relatively great length of these cables, it is necessary to hold the slack in them in a "cradle" (Fig. 359) when the border light is raised to its normal position behind the borders. If the slack is not thus supported, it dangles down where it would be in the way and possibly in view of the audience. The cradle should always be used at the end of the line holding the slack. Frequently the endeavor is made to hold this slack by merely tying the line around the cable but the abrupt bend thereby produced will ultimately break the conductors.

38*e*. 6. ¶*I*. THEATER WIRING—BORDERS AND PROSCENIUM For the wiring of the border proper, wire with *approved* slow-burning insulation must be used.

Slow-burning insulation wire should be used for wiring border lights because with them considerable heat is developed in a restricted space. The shape of the border-light trough is such that it tends to prevent circulation and promotes the retention of the heat. Rubber-insulated conductors may be "baked" under these conditions.

38*e*. 7. ¶*I*. THEATER WIRING—BORDERS AND PROSCENIUM. Borders must be suitably suspended, and if a wire rope is used same must be insulated by at least one strain insulator inserted at the border.

The suspensions for border lights should be arranged substantially as shown in Fig. 359. The border-light trough hangs from a 1¼-in. pipe batten. Lines from above, three or four in number, are made fast to the batten, spaced uniformly along its length and provide a support and a means of raising or lowering the border light. Border lights are heavy, hence wire ropes are used for their suspension in installations of any consequence. Where wire ropes are utilized, a strain insulator should be interposed, as shown in Fig. 259, between the end of the wire rope line and the pipe batten. This insulator is

inserted for practically the same reasons that dictate the provision of canopy insulators (*Rule* 30*a*, ¶*I*) in lighting fixtures suspended from gas pipes or other grounded objects. The strain insulator may be of the type used in street railway construction or may be of porcelain as in Fig. 162. The suspension cables are frequently counterweighted so that little effort is required to raise or lower the border lights.

f. STAGE AND GALLERY POCKETS

38*f*. ¶*I*. THEATER WIRING—STAGE AND GALLERY POCKETS. Must be of *approved* type, insulated from ground and controlled from switchboard, each receptacle to be of not less than 35 ampere rating for arc lamps nor 15 amperes for incandescent lamps, and each receptacle to be wired to its full capacity. Arc pockets to be wired with wire not smaller than No. 6 B. & S. gage and incandescent pockets with not less than No. 12 B. & S. gage.

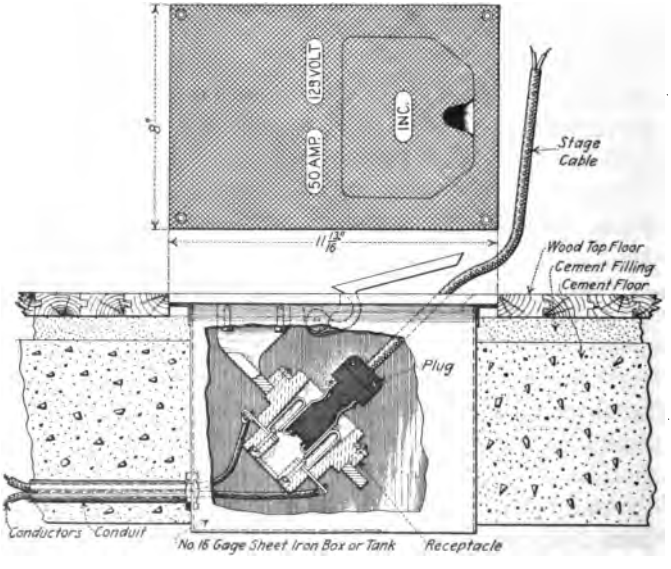


FIG. 360.—Stage floor pocket in position.

Stage pockets provide means of connecting cables serving portable electrical stage appliances to a source of supply. The floor pockets are arranged in the stage floor as shown in

Fig. 360. The wall pockets are mounted on or in the walls at the side of the stage or on the walls in the fly gallery (Fig.

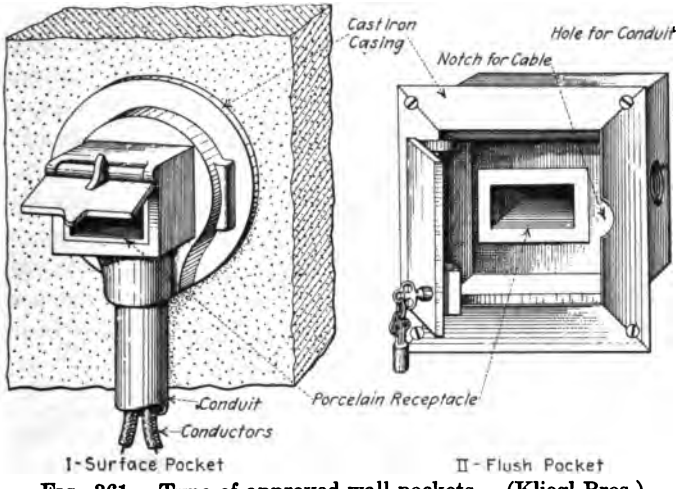


FIG. 361.—Type of approved wall pockets. (Kliegl Bros.)

361). Each pocket contains a receptacle, Fig. 362, wherein suitable attachment plugs connected to the stage cable ends may be inserted. These stage pockets should be constructed wholly of non-combustible

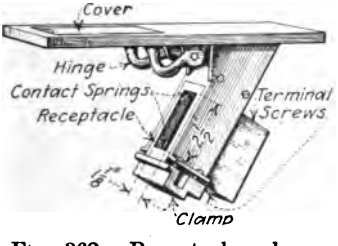


FIG. 362.—Receptacle and cover of stage floor pocket. (Sprague Blectric Co.)

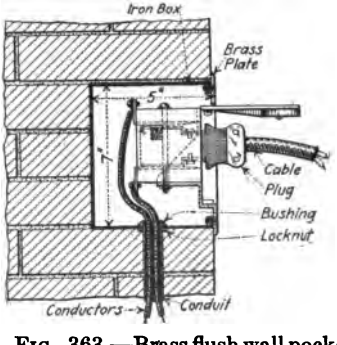


FIG. 363.—Brass flush wall pocket with plug in receptacle. (Kliegl Bros.)

materials and all bare current-carrying parts must be enclosed.

Single and multiple pockets can be purchased. The single pocket accommodates one plug only. Multiple pockets (Fig.

360) can be purchased which will accommodate either two, three or four plugs. The four-plug pocket is probably the most frequently used.

The plug handle should lie within the pocket when the plug is in position as shown in Fig. 360. For this reason receptacles of the construction of that of Fig. 363, which permits the plug handle to extend when the plug is in the receptacle, should be avoided. Where the plug handle "sticks out" as shown, the receptacle and the plug are liable to be broken accidentally.

Typical stage-plug construction is shown in Fig. 364. These plugs must be of simple design and rugged construction, inasmuch as they are subjected to the most severe usage. In the type shown the contact springs are of phosphor bronze.

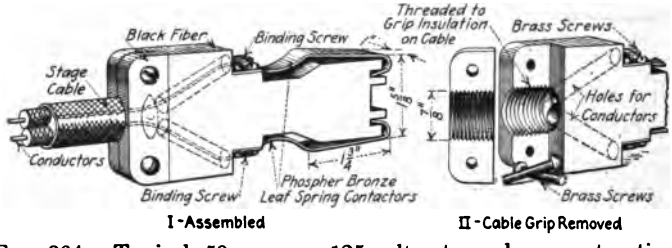


FIG. 364.—Typical 50-ampere, 125-volt, stage-plug construction. (Sprague Electric Co.)

The body of the plug is of hard fiber. A "grip" of fiber is provided to clamp the insulation, on the end of the cable, in the handle of the plug so that a strain cannot be imposed on the binding posts.

38*f*. ¶*11*. THEATER WIRING—STAGE AND GALLERY POCKETS. Plugs for arcs and incandescent pockets must not be interchangeable.

Plugs for arc and incandescent lamps are so designed that an incandescent plug will not fit an arc pocket. This protection is effected by slotting the arc plugs as shown in Fig. 365, and providing corresponding raised tongues on the sides of the arc-lamp receptacles. Arc-lamp receptacles should be capable of carrying not less than 35 amp. and incandescent lamp receptacles 15 amp. The receptacles of the two types are fused

accordingly; hence if an incandescent-lamp plug could be inserted in an arc receptacle, the conductors and incandescent-lamp circuits feeding from the plug might be greatly overloaded. The arc-lamp receptacles must be protected by fuses of sufficient capacity to carry the heavy arc-lamp currents. Thirty-two receptacles, 1,320 *watts* = 12 *amp.* on 110 *volts*, is the maximum load allowable on any incandescent-lamp circuit.

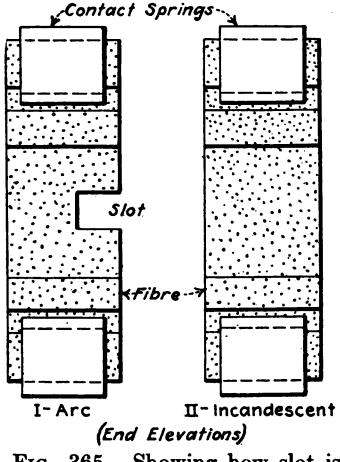


FIG. 365.—Showing how slot is cut in arc-lamp plug to accommodate tongue in arc-lamp receptacle. (Incandescent lamp plugs cannot be inserted in arc-lamp receptacle because these plugs are not grooved.)

g. SCENE DOCKS

38*g.* ¶*I.* THEATER WIRING —SCENE DOCKS. Where lamps are installed in Scene Docks, they must be so located and installed that they will not be liable to mechanical injury.

Lamps in scene docks (a scene dock is a part of the theater adjoining the stage where scenery is stored when not in use) are usually on the side walls. They should be protected by suitable guards or set in cavities in the wall so that scenery placed over them cannot contact with the lamps.

h. CURTAIN MOTORS

38*h.* ¶*I.* THEATER WIRING—CURTAIN MOTORS. Must be of enclosed type and installed so as to conform to the general requirements of this Code. (See No. 8.)

i. CONTROL FOR STAGE FLUES

38*i.* ¶*I.* THEATER WIRING—FLUE CONTROL. In cases where dampers are released by an electric device, the electric circuit operating same must be normally closed.

Stage flues are openings similar to sky lights placed in the roof directly over the stage. They should have doors which

will open automatically to the outside air in case of a fire on the stage, to permit the smoke and hot gases from the stage to flow out into the air and not into the auditorium. The supposition is that the asbestos curtain will be lowered in case of a fire, so that the smoke will be, in a measure at least, prevented from entering the auditorium through the proscenium. Frequently the doors in these flues are controlled by electrical magnetically-operated devices so that they can thereby be opened in case of a conflagration. In many cases, however, fusible links arranged in combination with counterweights afford an automatic opening arrangement.

38*i*. ¶*II*. THEATER WIRING—FLUE CONTROL. Magnet operating damper must be wound to take full voltage of circuit by which it is supplied, using no resistance device, and must not heat more than normal for apparatus of similar construction. It must be located in loft above scenery, and be installed in a suitable iron box with a tight, self-closing door.

38*i*. ¶*III*. THEATER WIRING—FLUE CONTROL. Such dampers must be controlled by at least two standard single pole switches mounted within *approved* iron boxes provided with self-closing doors without lock or latch, and located, one at the electrician's station and others as designated.

j. DRESSING ROOMS

38*j*. ¶*I*. THEATER WIRING—DRESSING ROOMS. Must be wired in *approved* conduit or armored cable. All pendant lights must be equipped with *approved* reinforced cord, armored cable, or steel armored flexible cord.

38*j*. ¶*II*. THEATER WIRING—DRESSING ROOMS. All lamps must be provided with *approved* guards which are sealed or locked in place.

k. PORTABLE EQUIPMENT

38*k*. ¶*I*. THEATER WIRING—PORTABLE EQUIPMENT. Arc lamps used for stage effects must conform to the following requirements:—

38*k*. 1. ¶*I*, THEATER WIRING—PORTABLE EQUIPMENT. Must be constructed entirely of metal of a thickness not less than No. 20 U. S. sheet metal gage except where use of *approved* insulating material is necessary.

38*k*. 2. ¶*I*. THEATER WIRING—PORTABLE EQUIPMENT. Must be substantially constructed, and so designed as to provide for

proper ventilation, and to prevent sparks being emitted from lamps when same are in operation, and mica must be used for frame insulation.

38*k*. 3. ¶*I*. THEATER WIRING—PORTABLE EQUIPMENT. Front opening must be provided with a self-closing hinged door frame, in which wire gauze or glass must be inserted, except in the case of lens lamps, where the front may be stationary, and a solid door be provided on back or side.

38*k*. 4. ¶*I*. THEATER WIRING—PORTABLE EQUIPMENT. Must be so constructed that neither carbons nor live parts will be brought into contact with metal of hood during operation, and arc lamp frames and standards must be so installed and protected as to prevent the liability of their being grounded.

Portable electrical stage equipment comprises lens arc lamps, Fig. 366, olivette lamps, Fig. 367, bunch lights, Fig. 368, strip lights, Fig. 369, and similar devices. Obviously such apparatus must be constructed very carefully and ruggedly in order to minimize fire hazard. The illustrations show typical construction.

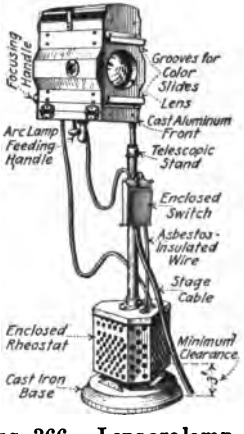


FIG. 366.—Lens arc lamp. (Kliegl Bros.)

Hand-fed arc lamps (Fig. 370) are used in stage lighting where it is desired to obtain a concentrated light of great intensity. Automatic feed lamps, although they have been tried, have never proved successful for this service because of the fact that they flicker when they feed. The hand-fed lamps require constant attention and feeding, but in spite of this disadvantage they will, if properly handled, produce an intense non-flickering light.

Tungsten or Mazda stage lamps (Fig. 367) have been used to some extent since the development of the high-candle-power, gas-filled incandescent lamps and have the advantage that they require no attendance after having been set. They produce a powerful, white, penetrating light.

38*k*. 5. ¶*I*. THEATER WIRING—PORTABLE EQUIPMENT. Switch on standard must be so constructed that accidental contact with any live portion of same will be impossible.

Switches on portable arc-lamp stands should, as suggested in Fig. 366, be entirely enclosed to prevent any possibility of accidental contact with the switch blades.

38*k*. 6. ¶*I*. THEATER WIRING—PORTABLE EQUIPMENT. All stranded connections in lamp and at switch and rheostat must be provided with *approved* lugs.

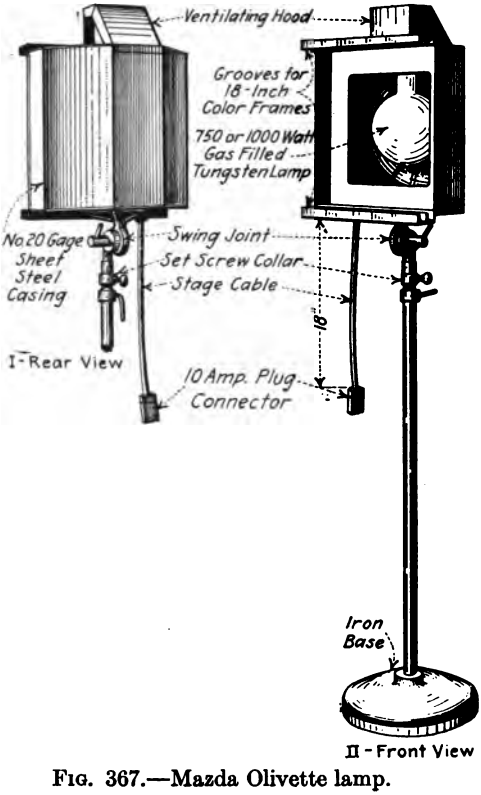


FIG. 367.—Mazda Olivette lamp.

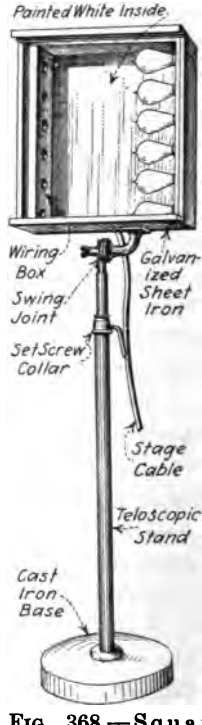


FIG. 368.—Square head, twelve-lamp, bunch light. (Kliegl Bros.)

38*k*. 7. ¶*I*. THEATER WIRING—PORTABLE EQUIPMENT. Rheostats must be plainly marked with their rated capacity in volts and amperes, and, if mounted on standard, must be raised to a height of at least three inches above floor. Resistance must be enclosed in a sub-

stantial and properly ventilated metal case which affords a clearance of at least one inch between case and resistance element.

38*k*. 8. ¶*I*. THEATER WIRING—PORTABLE EQUIPMENT. A competent operator must be in charge of each arc lamp, except that one operator may have charge of two lamps when they are not more than ten feet apart, and are so located that he can properly watch and care for both lamps.

l. BUNCHES

38*l*. ¶*I*. THEATER WIRING—BUNCHES. Must be substantially constructed of metal and must not contain any exposed wiring.

A bunch light, Fig. 368, is an arrangement comprising a group of from 6 to possibly 20 tungsten incandescent lamps arranged in a suitable reflector and mounted on an iron stand. These lights may be used where corners or recesses in scene settings must be illuminated in order to eliminate shadows.

38*l*. ¶*II*. THEATER WIRING—BUNCHES. The cable feeding same must be tubed in an approved manner where passing through the metal, and must be properly secured to prevent any mechanical strain from coming on the connection.

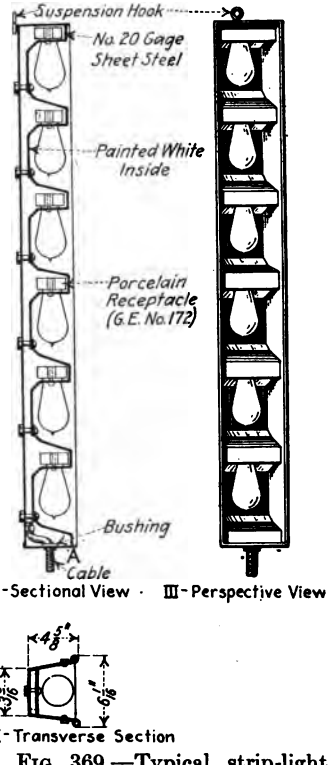


FIG. 369.—Typical strip-light construction. (Sprague Electric Co.)

m. STRIPS

38*m*. ¶*I*. THEATER WIRING—STRIPS. Must be constructed of steel of a thickness not less than No. 20 U. S. Sheet Metal gage, treated to prevent oxidation, and suitably stayed and supported and so designed that flanges will protect lamps.

Strips or strip lights (Fig. 369) have, in general, about the same application as have bunch lights, that is, they are fre-

quently used for illuminating detached or small spaces. However, the strip lights are arranged so that they may be hung on wings or scenery, or that they may be laid on the floor or supported back of a low setting to eliminate shadows. Their construction is, as outlined in the illustration, similar to that used for footlights and borders.

38*m*. ¶*II*. THEATER WIRING—STRIPS. Cable must be tubed in a suitable manner where passing through the metal, and must be properly secured to prevent serious mechanical strain from coming on the connections.

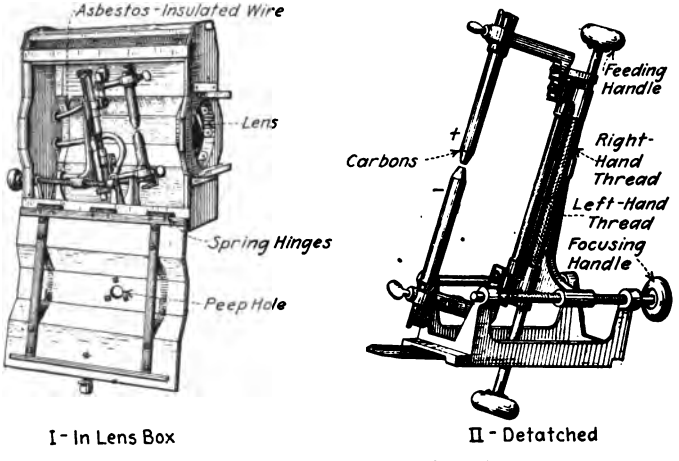


FIG. 370.—Hand-feed theatrical arc lamps.

Where cable passes through a strip-light casing, it is particularly liable to injury due to its being bent back and forth. It should, therefore, be protected at that point, *A*, Fig. 369, by a bushing—preferably of heavy porcelain—as shown.

38*m*. ¶*III*. THEATER WIRING—STRIPS. Must be wired in *approved* conduit or armored cable, each lamp receptacle being enclosed within an *approved* outlet box, or the lamp receptacles may be mounted in an iron or steel box, metal to be of a thickness not less than No. 20 U. S. Sheet Metal gage, treated to prevent oxidation, so constructed as to enclose all wires. Wires to be soldered to lugs of receptacles.

n. PORTABLE PLUGGING BOXES

38*n.* ¶*1.* THEATER WIRING—PORTABLE PLUGGING BOXES. Must be constructed so that no current carrying part will be exposed, and each receptacle must be protected by *approved* fuses mounted on slate or marble bases and enclosed in a fireproof cabinet equipped with self-closing doors. Each receptacle must be constructed to carry thirty amperes without undue heating, and the busbars must have a carrying capacity equivalent to the current required for the total number of receptacles, and *approved* lugs must be provided for the connection of the master cable.

Portable plugging boxes (Fig. 371) are really movable distribution cabinets at which branch circuits to various portable stage-lighting apparatus may be connected through fuses to the

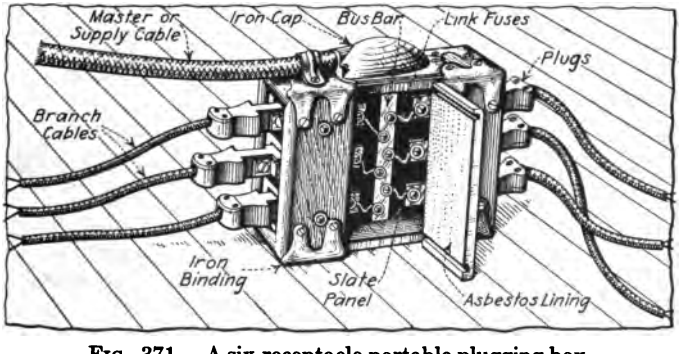


FIG. 371.—A six-receptacle portable plugging box.

source of supply. In other words, one of these plugging boxes is a sort of portable stage pocket. They are sometimes called "spider boxes." Link fuses are used in them because of the compact construction thereby afforded. Link fuses are permissible in this case inasmuch as they are entirely enclosed and the enclosing cabinet meets the provisions of *Rule* 67, *e* to *j*. Plugging boxes are made to accommodate from 2 to 12 branch-circuit plugs. They can be arranged for three-conductor master cables, for service from a three-wire system. They are much used by "road" companies. The master cable (which may have a capacity of 30 or more amp. for each plug branch circuit) is frequently connected to terminals

provided therefor on the stage switchboard or to a fused switch located at some convenient point on the stage walls.

o. PIN PLUG CONNECTORS

38o. ¶*I*. THEATER WIRING—PIN PLUG CONNECTORS. Must be of an *approved* type, so installed that the "female" part of plug will be on live end of cable, and must be so constructed that tension on the cable will not cause serious mechanical strain on the connections.

Pin-plug connectors Fig. 372, provide a means of connecting portable stage apparatus to the cable serving them and are in effect a sort of a receptacle-and-attachment-plug combination. Some device should always be provided on these connectors to grip the insulation of the cable, thereby preventing a stress being imposed on the binding post if the cable is strained.

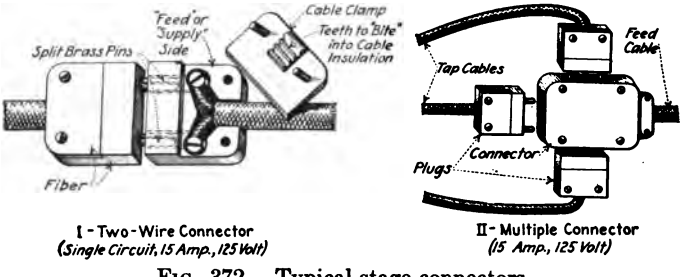


FIG. 372.—Typical stage connectors.

p. PORTABLE CONDUCTORS

38p. ¶*I*. THEATER WIRING—PORTABLE CONDUCTORS. Flexible conductors used from receptacles to arc lamps, bunches and other portable equipments must be *approved* stage cable except that for the purpose of feeding a stand lamp under conditions where conductors are not liable to severe mechanical injury, an *approved* reinforced cord may be used, provided cut-out designed to protect same is not fused over ten amperes capacity.

Stage cable is made as specified in *Rule* 51, *Table T*, and *d*, *g* and *h*. This specially constructed cable should always be used for portable stage apparatus except where a connection is to be made to a table lamp on the stage. In this case, the large stage cable would be unsightly; hence reinforced lamp

cord (*Rule* 51*f* and *Table*) may be used, provided fuses of not over 10-amp. capacity protect the cord.

q. LIGHTS ON SCENERY

38*q*. ¶*I*. THEATER WIRING—LIGHTS ON SCENERY. **Where brackets are used they must be wired entirely on the inside, fixture stem must come through to the back of the scenery and end of stem be properly bushed and fixtures to be securely fastened in position.**

Bracket lights on scenery can be arranged substantially as shown in Fig. 373. These brackets must always be so constructed that they can be readily placed on and removed from

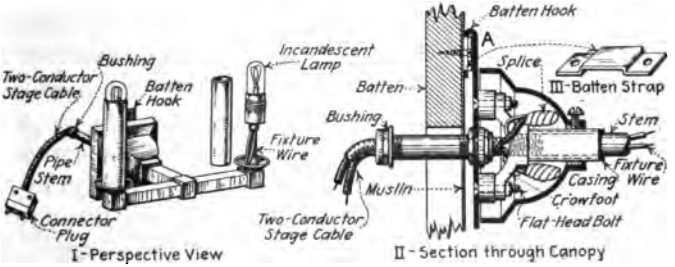


FIG. 373.—Arrangement of bracket light for use on scenery.

the scenery because it is necessary to take them down each time a scene is disassembled. The scenery always lies flat when stored, hence objects projecting permanently from its surface for any considerable distance are out of the question. A batten hook (*A*, Fig. 373) hangs in a sheet-metal batten strap (*III*) which is screwed to the scene batten. The pipe bushing carrying the conductors extends to the back of the batten through a slit cut in the canvas. The bracket is connected to the source of supply with a connector plug.

r. STRING OR FESTOONED LIGHTS

38*r*. ¶*I*. THEATER WIRING—STRING OR FESTOONED LIGHTS. **Wiring of same must be of *approved* type, joints to be properly made, soldered and taped, and staggered where practicable.**

38*r*. ¶*II*. THEATER WIRING—STRING OR FESTOONED LIGHTS. **Where lamps are used in lanterns or similar devices, *approved* guards must be employed.**

s. SPECIAL ELECTRIC EFFECTS

38s. ¶*I*. THEATER WIRING—SPECIAL ELECTRICAL EFFECTS. Where devices are used for producing special effects such as lightning, waterfalls, etc., the apparatus must be so constructed and located that flames, sparks, etc., resulting from the operation cannot come in contact with combustible material.

The arrangement of devices for the production of electrical effects should always be such that a conflagration cannot originate from the operation thereof. For example, the automatic *lightning striker* shown in Fig. 374 is enclosed in a case composed of sheet metal and wire netting, so that contact with the current-carrying parts is impossible and so that the hot particles of carbon cannot fall from the case. One or a number of these strikers, each in series with a resistance across the source of e.m.f., may be connected at various points overhead about the stage. The solenoid and the arcing contacts are in series so that when the operator connects the device in the circuit, by closing the switch, the carbon continues to rise and fall, due to the electric—vibrating—bell action of the device, so long as it is connected to the circuit. A series of flashes of light similar to that produced by lightning is the result.

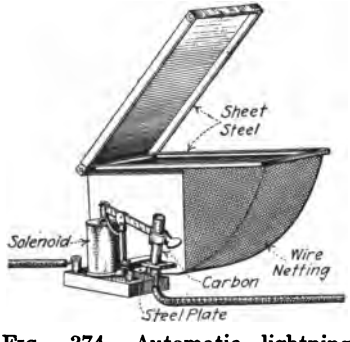


FIG. 374.—Automatic lightning striker (20 amp., 125 volts).

t. AUDITORIUM

38t. ¶*I*. THEATER WIRING—AUDITORIUM. All wiring must be installed in *approved* conduit, metal moulding or armored cable. Where receptacles are used they must be enclosed in approved boxes.

38t. ¶*II*. THEATER WIRING—AUDITORIUM. Exit lights must not have more than one set of fuses between same and service fuses.

Exit lights are considered (*Rule* 38*a*, ¶*I*) as emergency lights hence must be fed from a separate service with the other emergency lights as hereinbefore described. Furthermore,

only one set of fuses, as diagrammed in Figs. 344 and 345, is permitted between the exit lights and the entrance switch and cut-out. Exit lights are frequently enclosed in a metallic case constructed as detailed in Fig. 375. The lamp is wholly enclosed in the cast-iron box which may be either held to the surface of the wall as shown or set with its outer face flush. The wiring is in conduit, as all of the emergency-light wiring must be.

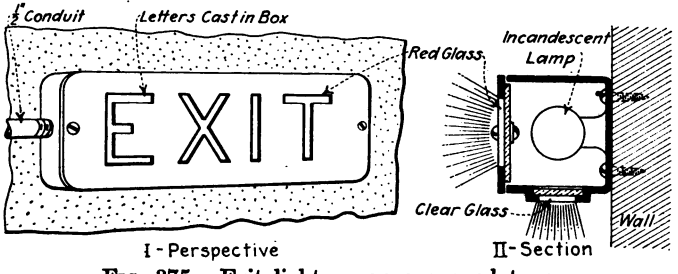


FIG. 375.—Exit light on an approved type.

38*t*. ¶*III*. THEATER WIRING—AUDITORIUM. Exit lights and all lights in halls, corridors or any other part of the building used by audience, except the general auditorium lighting, must be fed independently of the stage lighting, and must be controlled only from the lobby or other convenient place in front of the house.

The exit-light circuits must be controlled from the front of the house as shown in Figs. 344 and 345. Usually the switch for their control is located in the emergency-light distributing cabinet in the box-office. It is undesirable to have these lights controlled from the stage switchboard because when a fire occurs in a theater it frequently originates on the stage.

38*t*. ¶*IV*. THEATER WIRING—AUDITORIUM. All fuses must be enclosed in *approved* cabinets.

u. MOVING PICTURE EQUIPMENTS OTHER THAN THOSE OF APPROVED MINATURE TYPE

38*u*. 1. ¶*I*. THEATER WIRING—MOVING PICTURE EQUIPMENTS. *Arc Lamps*.—Arc lamps must be constructed so far as practicable in accordance with the requirements of No. 38 *k*, 1, 2, 3, 4 and 6, and incandescent lamps must be suitably enclosed.

38*u*. 2. ¶*I*. THEATER WIRING—MOVING PICTURE EQUIPMENTS. *Rheostats*.—Rheostats, transforming devices or any substitute therefore must be of types expressly designed and approved for the purpose. Their installation and location must be subject to approval as parts of the moving picture machine.

38*u*. 3. ¶*I*. THEATER WIRING—MOVING PICTURE EQUIPMENTS. *Top and Bottom Reels*.—Must be enclosed in steel boxes or magazines, each with an opening of *approved construction* at bottom or top, so arranged as not to permit entrance of flame to magazine. No solder is to be used in the construction of these magazines. The front side of each magazine must consist of a door swinging horizontally, and be provided with a substantial latch.

38*u*. 4. ¶*I*. THEATER WIRING—MOVING PICTURE EQUIPMENTS. *Automatic Shutter*.—Must be provided and must be so constructed as to shield the film from the beam of light whenever the film is not running at operating speed. Shutter must be permanently attached to the gate frame.

38*u*. 5. ¶*I*. THEATER WIRING—MOVING PICTURE EQUIPMENTS. *Extra Films*.—Must be kept in individual metal boxes equipped with tight-fitting covers.

38*u*. 6. ¶*I*. THEATER WIRING—MOVING PICTURE EQUIPMENTS. *Machine Operation*.—Must be of an *approved* type. If driven by a motor, must be of a type expressly designed and approved for such operation, and when so approved, motor driven machines, when in charge of a skilled operator, may be authorized under special permission in writing given in advance.

38*u*. 7. ¶*I*. THEATER WIRING—MOVING PICTURE EQUIPMENTS. *Machine Enclosure*.—Machine must be placed in an enclosure or house made of suitable fireproof material; must be properly lighted and large enough for operator to walk freely on either side of or back of machine.

38*u*. 7. ¶*II*. THEATER WIRING—MOVING PICTURE EQUIPMENTS. *Machine Enclosure*.—Ventilation for permanent booths must be provided by means of a vent pipe having a cross section of not less than 78 square inches; said pipe leading to the outside of the building or to a special non-combustible vent flue. All parts of vent pipe to be at least one inch from any combustible material or separated therefrom by means of approved non-combustible heat insulating material not less than one-half inch in thickness. A fan capable of exhausting fifty cubic feet of air per minute shall be installed and arranged in such a way that gas and smoke passing through the vent flue shall not come in contact with the motor. The motor must be connected to the emergency service and must not be controlled from the booth.

38*u*. 7. ¶*III*. THEATER WIRING—MOVING PICTURE EQUIPMENTS. *Machine Enclosure*.—All openings into this booth must be arranged so as to be entirely closed by doors or shutters constructed of

the same or equally good fire-resisting material as the booth itself. Doors or covers must be arranged so as to be held normally closed by spring hinges or equivalent devices.

38*u*. 8. ¶*I*. THEATER WIRING—MOVING PICTURE EQUIPMENTS. *Reels Containing Films Under Examination or in Process of Rewinding.*—Must be enclosed in magazines or *approved* metal boxes similar to those required for films in operation, and not more than two feet of film shall be exposed in booth.

v. MOVING PICTURE EQUIPMENTS OF APPROVED MINIATURE TYPE FOR HOME, LECTURE AND SIMILAR PURPOSES

38*v*. 1. ¶*I*. THEATER WIRING—MINIATURE MOVING PICTURE EQUIPMENTS. All equipments must be expressly approved, and such approval must cover the entire machine including all attachments, current-controlling devices and other parts employed, including also the film.

38*v*. 2. ¶*I*. THEATER WIRING—MINIATURE MOVING PICTURE EQUIPMENTS. The entire equipment must consume not more than 660 watts.

38*v*. 3. ¶*I*. THEATER WIRING—MINIATURE MOVING PICTURE EQUIPMENTS. Arc lamps must be constructed so far as practicable in accordance with the requirements of No. 38, *k*, 1, 2, 3, 4 and 6, and incandescent lamps must be suitably enclosed.

38*v*. 4. ¶*I*. THEATER WIRING—MINIATURE MOVING PICTURE EQUIPMENTS. Rheostats, transformers, switches and other similar current-controlling devices must be attached to and form a part of the machine, must have no live parts exposed, and must comply with the requirements of No. 65 and No. 78 or No. 81 *a*, *b*, *c*.

38*v*. 5. ¶*I*. THEATER WIRING—MINIATURE MOVING PICTURE EQUIPMENTS. Films must be of an *approved* slow-burning type having a permanent distinctive marker.

38*v*. 6. ¶*I*. THEATER WIRING—MINIATURE MOVING PICTURE EQUIPMENTS. Machines must be so constructed that they cannot be used with films employed on the full-sized commercial moving picture machine. This may be accomplished by using a film of special width or with special perforations or by any other approved means.

38*v*. 6. ¶*I*. NOTE. THEATER WIRING—MINIATURE MOVING PICTURE EQUIPMENTS. The regular film which is not allowed on miniature machines is 1¾ inches wide and has on each edge 5.4 perforations per inch.

38*v*. 7. ¶*I*. THEATER WIRING—MINIATURE MOVING PICTURE EQUIPMENTS. Machines must be marked with the name or trade-mark of the maker, and with the voltage and current rating for which they are designed, and be plainly marked, "For use with slow-burning films only."

39. OUTLINE LIGHTING.

(*Other than Signs on Exterior of Buildings*)

39*a*. ¶*1*. OUTLINE LIGHTING. **Must be connected only to low-potential systems.**

39*b*. ¶*1*. OUTLINE LIGHTING. **Open or conduit work or metal trough construction may be used but moulding will not be permitted.**

Outline-lighting wiring may be either open, in conduit or of metal-trough construction similar to that used for theater footlight, border-light and side-light wiring. Fig. 376 shows a typical outline-lighting conduit installation. The construc-

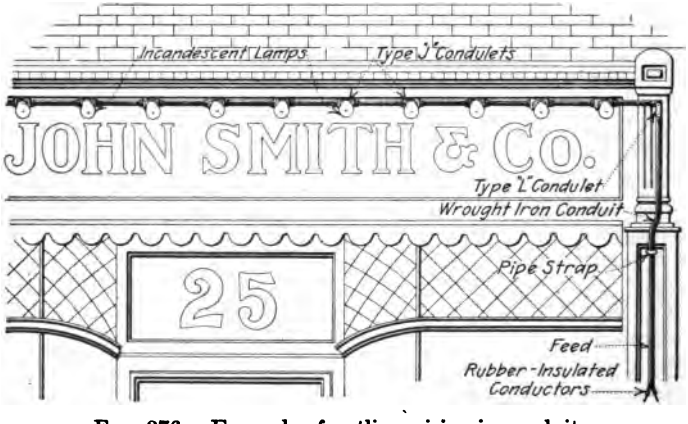


FIG. 376.—Example of outline wiring in conduit.

tion of metal wiring troughs is delineated in Figs. 353 to 355. Molding wiring should not be used for this service because it is not water-tight and hence, due to the exposed position of the outline-lighting circuits on buildings, excessive moisture would enter molding, if it were used, and make trouble. Where conduit is applied, all of the fittings, as indicated in Fig. 376 should be of the screw-thread type. Pressed-steel outlet boxes in which the conduit is held by locknuts should not be installed because they are not water-tight.

39*c*. ¶*1*. OUTLINE LIGHTING. **Where flexible tubing is required, the ends must be sealed and painted with moisture repellant and kept at least one-half inch from surface wired over.**

39*d*. ¶*I*. OUTLINE LIGHTING. Wires for use in rigid or flexible steel conduit must comply with requirements for conduit work. Where armored cable is used, the conductors must be protected from moisture by lead sheath between armor and insulation.

39*e*. ¶*I*. OUTLINE LIGHTING. Must be protected by its own cut-out, and controlled by its own switch; single pole switches must not be used. Cut-outs, switches, flashers and similar appliances must be of *approved* types and be installed as required by the Code for such appliances, and, if outside the building, must, with the exception of transformer of weatherproof type, be installed in *approved* weatherproof cabinets.

39*f*. ¶*I*. OUTLINE LIGHTING. Circuits must be so arranged that not more than 1,320 watts will be dependent upon one cut-out.

39*g*. ¶*I*. OUTLINE LIGHTING. Sockets and receptacles must be of the keyless porcelain type and wires must be soldered to lugs on same. Miniature receptacles will not be approved for outdoor work.

Sockets or receptacles for open-work outline-lighting wiring should be of the keyless type because key sockets will ultimately give trouble if exposed to moisture. Fig. 377 indicates the type of receptacle that should be applied. Note that it provides a 1-in. separation between the conductors and the surface wired over, as is specified in *Rule* 39*h*, ¶*I*.

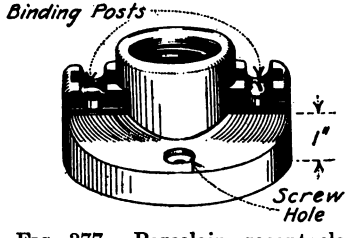


FIG. 377.—Porcelain receptacle used for outline open-work wiring. (It separates the conductors 1 in. from the surface wired over.)

39*h*. ¶*I*. OUTLINE LIGHTING. For open work, wires must be *approved* rubber covered, not less than No. 14 B. & S. gage and must be rigidly supported on non-combustible, non-absorptive insulators, which separate the wires at least one inch from the surface wired over. Rigid supporting requires, under ordinary conditions where wiring over flat surfaces, supports at least every four and one-half feet. If the wires are liable to be disturbed, the distance between supports should be shortened. In those parts of circuits where wires are connected to *approved* receptacles which hold them at least one inch from surface wired over, and which are placed not over one foot apart, such receptacles will be considered to afford the necessary support and spacing of the wires. Between receptacles more than one foot, but not less than two feet apart, an additional non-combustible, non-absorptive insulator maintaining a separation and spacing equivalent to the receptacles must be used. Except as above

specified, wires must be kept apart at least two and one-half inches for voltages up to 300, and four inches for higher voltages.

39*i*. ¶*I*. OUTLINE LIGHTING. For metal trough construction, the troughs and other details must comply with the requirements of No. 83 *a* to *f*, inclusive.

40. CAR WIRING AND EQUIPMENT OF CARS.

These rules, a to k inclusive, apply to all cars or locomotives used for electric railway service, and cars or locomotives for other railway service, which are equipped with electric circuits, and operating on either low or high potential systems.

The rules relating to car wiring and carhouses are, because of their special application, omitted from this book. They will be found in full in the *National Electrical Code.*

41. CAR HOUSES.

NOTE. See *National Electrical Code* for the text of this rule in full.

41*A*. LIGHTING AND POWER FROM RAILWAY WIRES

41*A*. ¶*I*. CAR HOUSES—LIGHTING AND POWER FROM RAILWAY WIRES. Must not be permitted, under any pretence, in the same circuit with trolley wires with a ground return, except in electric railway cars, electric car houses, power houses, passenger and freight stations connected with the operation of electric railways.

42. GARAGES.

For the purposes of this rule a garage is considered as that building or portion of a building in which one or more self-propelled vehicles carrying volatile inflammable liquid for fuel or power are kept for use, sale, storage, rental, repair, exhibition or demonstration purposes; and all that portion of a building that is on or below the floor or floors on which such vehicles are kept which is not separated therefrom by tight unpierced fire walls and fire-resisting floors.

Garages may frequently be classed as damp places and are always more or less hazardous because of the presence of oil and gasoline. It is, therefore, obvious that stringent wiring requirements are imperative.

In addition to the general requirements of the Code the following rules shall apply:—

42*a*. ¶*I*. GARAGES. In garages used for more than two vehicles, as above, all conductors except those required for pendant lamps or portable connections must be installed in *approved* metal conduit or *approved* armored cable, except that *approved* metal moulding may be used only in offices and showrooms. Metal conduit, armored cable or metal moulding

must be so installed that all outlet and junction boxes shall be located at least four feet above the floor. In garages used for one or two vehicles, as above, conduit or armored cable construction is not required.

42*b*. ¶*I*. GARAGES. Flexible cord for pendant lights must be *approved* reinforced cord.

42*c*. ¶*I*. GARAGES. Flexible cords for portable lamps, motors or other apparatus must be *approved* cord designed for rough usage. The portable cord must carry the male end of an *approved* pin plug connector or equivalent, the female end being of such design or so hung that the connector will break apart readily at any position of the cable. The connector must be kept at least four feet above the floor.

Pin-plug connectors for garages may be similar to those required for portable theater-stage appliances, as illustrated in Fig. 372. The male end of a pin-plug connector is the part from which the pins extend. The female part is the receptacle portion. The cord to which the female portion of the pin-plug connector is attached and through which the energy is derived should always be of such a length that its lower end will always be at least 4 ft. from the floor, to prevent any possibility of the connector receptacle contacting with things on the floor or dragging on it.

42*d*. ¶*I*. GARAGES. Flexible cable for charging must be of *approved* theatre stage type, this cable carrying parts of *approved* connectors of at least fifty amperes capacity. The connectors must be of such design or so hung that at least one will break apart readily at any position of the cable. Current-carrying parts of connectors must be shielded to prevent accidental contact. The fixed, or wall connector, must be kept at least four feet above the floor, and if not located on switchboard or charging panel, must be protected against accidental contact.

Charging plugs and receptacles for garages may be of the same general design as those shown for theater-stage-wiring service in Figs. 360 to 363.

42*e*. ¶*I*. GARAGES. Cut-outs, switches and receptacles must be placed at least four feet above the door, except as provided in Section *g* below.

42*f*. ¶*I*. GARAGES. All portable lights must be equipped with *approved* keyless sockets of moulded composition for metal-sheathed porcelain type. These sockets must be equipped with handle, hook and substantial guard.

42*g*. ¶*I*. GARAGES. Switchboards and charging panels, at or upon which are mounted devices which in operation may produce a spark,

must be located in a room or enclosure provided for the purpose unless all such spark producing devices are at least four feet above the floor or surrounded by vapor proof enclosures.

42*h*. ¶*I*. GARAGES. Motors or dynamos, not actually a part of a vehicle, if not located at least four feet above the floor must be of the fully enclosed type. Motors located four feet or more above the floor, if not of the fully enclosed type, must be provided with wire screen of not less than No. 14 mesh over openings at commutator end.

43. ELECTRIC CRANES.

All wiring, apparatus, etc., not specifically covered by special rules herein given, must conform to the General Requirements of this Code, except that the switch required by No. 8 *c for each motor may be omitted.*

a. WIRING

43*a*. 1. ¶*I*. ELECTRIC CRANES—WIRING. All wires except bare collector wires, those between resistances and contact plates of rheostats and those subjected to severe external heat, must be *approved* rubber-covered and not smaller in size than No. 12 B. & S. Insulation on wires between resistances and contact plates of rheostats must conform to Section *d*, while wires subjected to severe external heat must have *approved* slow-burning insulation.

43*a*. 2. ¶*I*. ELECTRIC CRANES—WIRING. All wires excepting collector wires and those run in metal conduit or *approved* flexible cable must be supported by knobs or cleats which separate them at least one inch from the surface wired over, but in dry places where space is limited and the distance between wires as required by No. 26 *h* cannot be obtained, each wire must be separately encased in *approved* flexible tubing securely fastened in place.

43*a*. 2. ¶*II*. ELECTRIC CRANES—WIRING. Collector wires must be supported by *approved* insulators so mounted that even with the extreme movements permitted the wires will be separated at all times at least 1½ inches from the surface wired over. Collector wires must be held at the ends by *approved* strain insulators.

Collector or contact wires for traveling cranes may be arranged as shown in Figs. 378 and 379. The difference in these installations is that that of Fig. 378 shows a wooden crane runway and eye-bolts are used for tightening the contact wires. In Fig. 379, a steel runway is shown and the contact wires are tightened with turn-buckles. Strain insulators should always, as shown, be interposed between the ends of the contact wires and the terminal supports. Strap iron bars and structural-steel sections, such as small angles and tees are

frequently used for contact bars on crane runways instead of the usual hard-drawn copper contact wires. See the author's

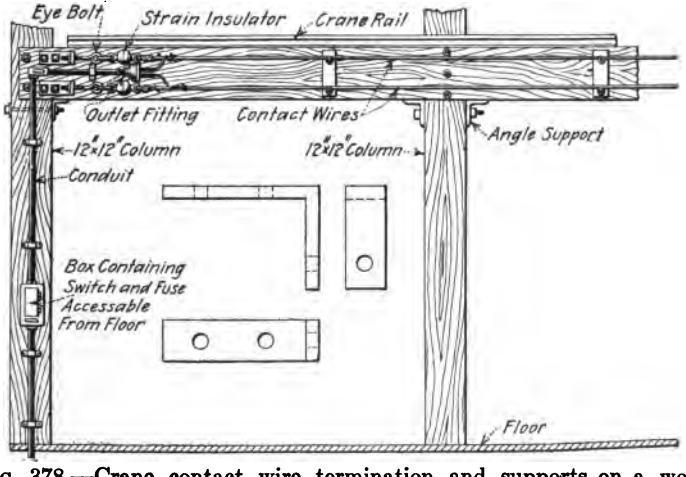


FIG. 378.—Crane contact wire termination and supports on a wood crane-runway.

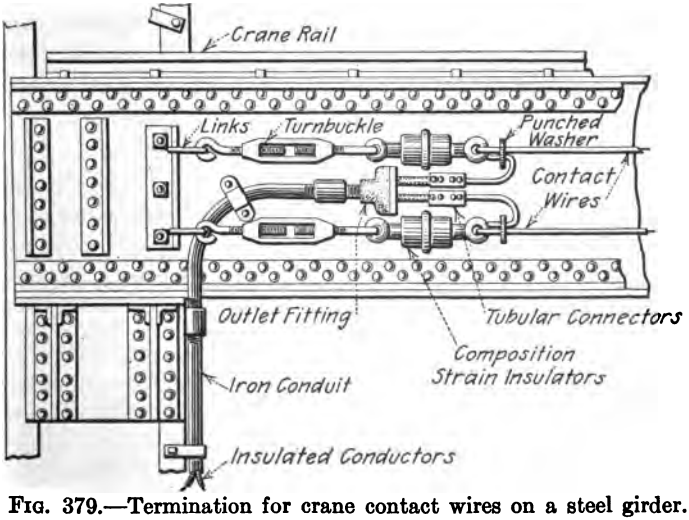


FIG. 379.—Termination for crane contact wires on a steel girder.

AMERICAN ELECTRICIANS' HANDBOOK for further and detailed information relating to crane wiring.

43a. 3. ¶I. ELECTRIC CRANES—WIRING. Main collector wires carried along the runways must be rigidly and securely attached to their insulating supports at least every 20 feet, and separated at least 6 inches when run in a horizontal plane; if not run in a horizontal plane, they must be separated at least 8 inches. If spans longer than 20 feet are necessary the distance between wires must be increased proportionately but in no case shall the span exceed 40 feet.

Intermediate supports along crane runways are usually, where the contacting member is a copper wire, erected substantially as shown in Fig. 380, which illustrates the arrangement of an intermediate support for the contact wires for a three-phase crane. It is ordinarily inadvisable to install out of doors a contact-wire support which is dependent on a wood block, as is that of Fig. 380. Where the crane runway is outside and exposed to the weather the best construction involves the use of figure-8 copper trolley wire supported on insulating hangers such as are used in street-railway overhead construction; see AMERICAN ELECTRICIANS' HANDBOOK for details. Where the figure-8 contact wire is thus supported, a collecting shoe slides along with the crane and bears against the contact wire.

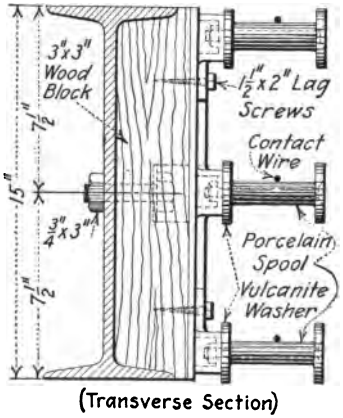


FIG. 380.—Intermediate supports for contact wires for a three-phase alternating-current crane on a 15-in. 42-pound I-beam.

43a. 4. ¶I. ELECTRIC CRANES—WIRING. Where bridge collector wires are over 80 feet long, insulating supports on which the wires may loosely lie must be provided at least every 50 feet.

43a. 4. ¶II. ELECTRIC CRANES—WIRING. Bridge collector wires must be kept at least 2½ inches apart, but a greater spacing should be used whenever it may be obtained.

43a. 5. ¶I. ELECTRIC CRANES—WIRING. Collector wires must not be smaller in size than specified in the following table for the various spans.

Distance between rigid supports. Feet	Size wire required. B. & S.
0 to 30	6
31 to 60	4
Over 60	2

b. COLLECTORS

43*b.* ¶*I.* ELECTRIC CRANES—COLLECTORS. Must be so designed that sparking between them and collector wires will be reduced to a minimum.

c. SWITCHES AND CUT-OUTS

43*c.* 1. ¶*I.* ELECTRIC CRANES—SWITCHES AND CUT-OUTS. The main collector wires must be protected by a cut-out and the circuit controlled by a switch. Cut-out and switch to be so located as to be easy of access from the floor.

43*c.* 2. ¶*I.* ELECTRIC CRANES—SWITCHES AND CUT-OUTS. Cranes operated from cabs must have a cut-out and switch connected into the leads from the main collector wires and so located in the cab as to be readily accessible to the operator.

43*c.* 3. ¶*I.* ELECTRIC CRANES—SWITCHES AND CUT-OUTS. Where there is more than one motor on a single crane, each motor lead must be protected by a cut-out located in the cab if there is one.

d. CONTROLLERS

43*d.* ¶*I.* ELECTRIC CRANES—CONTROLLERS. Must be installed according to No. 4, except that if the crane is located out doors the insulation on wires between resistances and contact plates of rheostats must be rubber where the wires are exposed to moisture and insulation is necessary and also where they are grouped. If the crane operates over readily combustible material, the resistances must be placed in an enclosure made of non-combustible material, thoroughly ventilated and so constructed that it will not permit any flame or molten metal to escape in the event of burning out the resistances. If the resistances are located in the cab, this result may be obtained by constructing the cab of non-combustible material and providing sides which enclose the cab from its floor to a height at least 6 inches above the top of the resistances.

e. GROUNDING OF IRON WORK

43*e.* ¶*I.* ELECTRIC CRANES—GROUNDING OF IRON WORK. The motor frames, the entire frame of the crane and the tracks must be permanently and effectually grounded.

Questions. Class C. (CONSTANT LOW-POTENTIAL SYSTEMS. 550 VOLTS OR LESS)

138. What type of insulation is approved for wires used in concealed knob-and-tube work? Why?

139. State the cases when fixture canopies must be insulated from the surfaces on which fixtures are supported?

140. How may wires be suitably protected when exposed to injury or interference where crossing timbers?

141. Why should both wires of a circuit be run in metal molding for alternating-current systems and, preferably, also for direct-current systems?

142. State the regulations governing bends made in armored-cable runs.

143. How may the number of different wires that may be installed in a given size conduit be ascertained?

144. How should chain fixtures be wired?

145. How should portable lamps be protected against contact with inflammable materials?

146. What are the regulations affecting cut-outs for groups of mercury vapor lamps mounted in frames?

147. State briefly how armored cable should be grounded. What size of ground wire may be used?

148. What is the greatest difference of potential allowable between wires carried in wood or metal molding?

149. How must wires be bushed when entering cabinets, cut-out boxes or junction boxes?

150. Under what conditions may twin wires be used?

151. How should concealed knob-and-tube wires be run if it is impracticable to support them on non-combustible glass or porcelain supports?

152. What are the special requirements that apply to armored cable when installed in places subject to moisture?

153. What insulation is approved for wires run in conduit?

154. State the conditions under which "flat" canopies may be installed in fixture work?

155. What protection must be provided for an incandescent lamp and socket when installed in a room where inflammable gases may exist?

156. What excess current-carrying capacity should branch conductors serving an arc lamp have over that of the lamp?

157. What general requirements affect the installation of high potential, vacuum-tube systems?

158. Name and describe one approved method of supporting conductors in a vertical conduit run?

159. How are armored cables terminated when entering terminal or junction boxes?

160. What special protection must be provided where metal molding passes through floors?

161. Of what special construction must fixtures be if installed out of doors?

162. What is the smallest permissible diameter of the inlet of a socket when not attached to a fixture?

163. For what purposes may flexible cord be used?

164. How should economy and compensator coils for arc lamps be mounted?

165. How should flexible cord be connected to fittings? Describe.

166. How should the wires supporting a weatherproof socket be connected to the branch-circuit conductors?

167. What is the smallest size wire permissible in fixture work?

168. When should fixtures be tested for short circuits?

169. How should fixtures be supported when they cannot be attached to gas pipes or conduit?

170. How must outlet boxes in conduit runs be installed with respect to the surface of the wall or ceiling in which they appear?

171. Should conductors in vertical conduits be supported and at what intervals? Why?

172. How should wires for knob-and-tube work be supported and spaced?

173. Why must conduit systems be "continuous from outlet to outlet?"

174. What requirements are in effect regarding making bends in conduit runs?

175. Under what conditions must fixtures be insulated from their supports?

176. What is the maximum permissible difference of potential between wires contained in or attached to the same fixture?

177. What type of socket must be used for installations in wet or damp places or in places where corrosive vapors exist?

178. When fixtures are wired on the outside, what special precautions are necessary to protect the conductors?

179. How is the backing of metal molding secured in position on the supporting surface?

180. What is the greatest allowable difference of potential between the conductors of flexible cord?

181. What is the minimum permissible distance at which outside arc lamps may be installed above the sidewalk?

182. What kind of protection must be provided for wires carried on side walls? Describe in detail.

183. May each wire in a system be run in a separate conduit (*a*) for alternating-current systems, and (*b*) for direct-current systems? If not, why not? Explain in each case.

184. Under what conditions may armored cables be installed without the use of outlet boxes or outlet plates at termination or junction boxes?

185. Why should the protective non-conducting coating on conduits be scraped off before making ground connections thereto?

186. Of what size must the wire be for grounding metal molding systems?

187. When must approved slow-burning, fixture wire be used in show-case wiring?

188. Under what conditions is it mandatory to install keyless type sockets?

189. How should cut-outs be arranged for arc lamps on constant potential circuits?

190. State the smallest size and the type of wire permitted, and how it must be installed, when a weatherproof socket is supported independent of a fixture?

191. What kind of cord must be used in show-window wiring?

192. Is there any particular reason why metal molding should be continuous from outlet to outlet, and if so, what is it?

193. How should wires be run in unfinished attics?

194. When run in damp places, how must wires be supported?

195. How many wires may be carried in a single length of metal molding?

196. When should wires be drawn into a conduit system?

197. What are the requirements respecting the continuity of armored cable runs?

198. What type of insulation may wires have for use in open work in dry places?

199. How must such wires be supported?

200. How must the wires in a concealed knob-and-tube installation be terminated at outlets?

201. What is the most important thing to remember in regard to their location when installing junction boxes?

202. Under what conditions may metal molding runs pass through partitions without the provision of additional protection?

203. What insulation is required for wires exposed to dampness, vapor, or acid fumes?

204. What protection must be provided for flexible cord where it enters a socket?

205. State the type of insulation required for wires run in molding, either wood or metal.

206. What provision should be made for the protection of wires where the conduit system enters a junction box?

207. What size wire may be used for wiring gallery and stage pockets?

208. How should wires be attached to stage footlight receptacles?

209. At what distance from inflammable material should transformers be installed?

210. How should the main collector wires along a crane runway be supported?
211. What are the requirements as to grounding of crane motor installations?
212. What type of condutors may be used with portable stage equipment?
213. What is the requirement regarding the feeding of exit light circuits?
214. How should border and proscenium sidelights be prevented from contacting with scenery or other combustible materials?
215. Under what conditions, in gas-filled incandescent lamp circuits, may more than 660 watts be dependent on one cut-out?
216. How should dimmers in theater wiring be wired with respect to the balance of the circuit of which they form a part.
217. What type of insulation must wires have if used for wiring of stage borders?
218. In outline lighting wiring, what are the requirements when flexible tubing is used?
219. With the exception of pendant lamps and portable connections, how must conductors in garage wiring be run?
220. How are main crane-collector wires protected?
221. What type of sockets are permissible in garage wiring?
222. What are the requirements affecting the use of devices for creating special electrical effects on stages?
223. What type of sockets and receptacles are required for outline lighting wiring?
224. How are crane collector wires supported?
225. When may gas-filled incandescent lamps be used in show windows?
226. With stage border and proscenium sidelights, what is the maximum permissible wattage allowed under the protection of one cut-out?
227. What are some of the most important requirements regarding switchboards and charging panels installed in garages?
228. Describe briefly the different kinds of services that must be installed for supply in a theater. Explain why.
229. How should theater exit lights be fused?
230. When, in crane wiring, proper spacing cannot be obtained between wires, how must these wires be installed?
231. What are the requirements governing the installation of temporary decorative lighting systems?
232. Where should the magnet controlling a stage flue damper be located?
233. How should stage footlight receptacles be mounted?
234. What data or markings are required on rheostats for portable stage equipment?
235. State the requirements with regard to control of stage flue dampers.
236. What is the maximum permissible wattage which may be dependent upon one cut-out in outline lighting wiring?
237. Why should guard rails be provided around theater switchboards?
238. How must the wiring in theater dressing rooms be installed?
239. How should ventilation be provided for moving picture machine booths?
240. What kind of switches must not be used in outline lighting wiring circuits?
241. How must moving picture machines be enclosed?
242. What is the maximum permissible wattage consumption for miniature moving picture machines?
243. How far apart and how far from the surface wired over must wires used in open-work wiring in low-potential systems be located?
244. How should electric-crane installations be grounded?
245. What are the requirements governing the installation of motors in garages?
246. Where should emergency switches in car house underground feed circuits be located?
247. What requirements are in effect regarding the installation of temporary decorative lighting systems?
248. Where must keyless sockets be installed?

HIGH-POTENTIAL SYSTEMS

550 to 3,500 Volts

(Rules 44 to 46 inclusive)

Any circuit attached to any machine or combination of machines which develops a difference of potential between any two wires of over 550 *volts and less than* 3,500 *volts, shall be considered as a high-potential circuit, and as coming under this class, unless an approved transforming device is used, which cuts the difference of potential down to* 550 *volts or less. For* 550 *volt motor equipments a margin of ten per cent above the* 550 *volt limit will be allowed at the generator or transformer without coming under high-potential systems.*

44. WIRES.

(*See also Nos.* 16, 17, 18 *and* 20. *For construction rules see Nos.* 49 *and* 50)

44*a*. ¶*I*. WIRES. Must have an *approved* rubber-insulating covering.

44*b*. ¶*I*. WIRES. Must be always in plain sight, and never encased, except as provided for in No. 8 *b*, or where specially required.

44*c*. ¶*I*. WIRES. Must (except as provided for in No. 8 *b*), be rigidly supported on glass or porcelain insulators, which raise the wire at least one inch from the surface wired over, and must be kept about eight inches apart.

44*c*. ¶*II*. WIRES. Rigid supporting requires under ordinary conditions, where wiring along flat surfaces, supports at least about every four and one-half feet. If the wires are unusually liable to be disturbed the distance between supports must be shortened.

44*c*. ¶*III*. WIRES. In buildings of mill construction, mains of not less than No. 8 B. & S. gage, where not liable to be disturbed, may be separated about ten inches and run from timber to timber, not breaking around, and may be supported at each timber only.

44*d*. ¶*I*. WIRES. Must be protected on side walls from mechanical injury by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top (the wires passing through bushed holes) and extending not less than seven feet from the floor. When crossing floor timbers, in cellars, or in rooms where they might be exposed to injury, wires must be attached by their insulating supports to the under side of a wooden strip not less than one-half an inch in thickness.

45. TRANSFORMERS.

(*See also Nos.* 11, 14, 15 *and* 36. *For construction of Transformers see No.* 81)

Transformers must not be placed inside of buildings without special permission.

Oil-insulated transformers should never be placed inside of a building without special permission from the *Underwriters' Inspection Bureau* having jurisdiction. This requirement is perfectly general (*Rule* 36*a*) regardless of the voltage of the transformer. Air-cooled transformers operating at voltages below 550 may (*Rule* 36*b*, ¶*I*) be placed indoors without special protection but if the pressure on their primary or secondary windings exceeds 550, then special permission should be obtained prior to placing the transformer within a building.

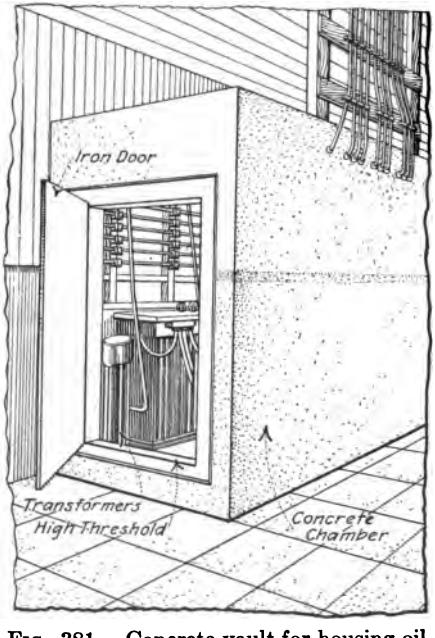


FIG. 381.—Concrete vault for housing oil-insulated and high-tension transformer.

45*a*. ¶*I*. TRANSFORMERS. Must be located as near as possible to the point at which the primary wires enter the building.

45*b*. ¶*I*. TRANSFORMERS. Must be placed in an enclosure constructed of fire-resisting material; the enclosure to be used only for this purpose, and to be kept securely locked, and access to the same allowed only to responsible parties.

A concrete transformer vault of the general type that is ordinarily required when transformers must be installed within a building is shown in Fig. 381. Note the high door sill. This is to prevent the oil from flowing out into the building in case one of the transformers "boils over" due to heavy over-

load or short-circuit. The door is of corrugated iron, rivetted on a steel frame. Although the door of the vault shown opens to the inside of the building it is better to have the door of a transformer vault open to the outside, so that in case of a fire in the transformer vault, smoke and hot gases will flow to the outer air rather than to the interior of the structure. Fig. 107 illustrates a similar example.

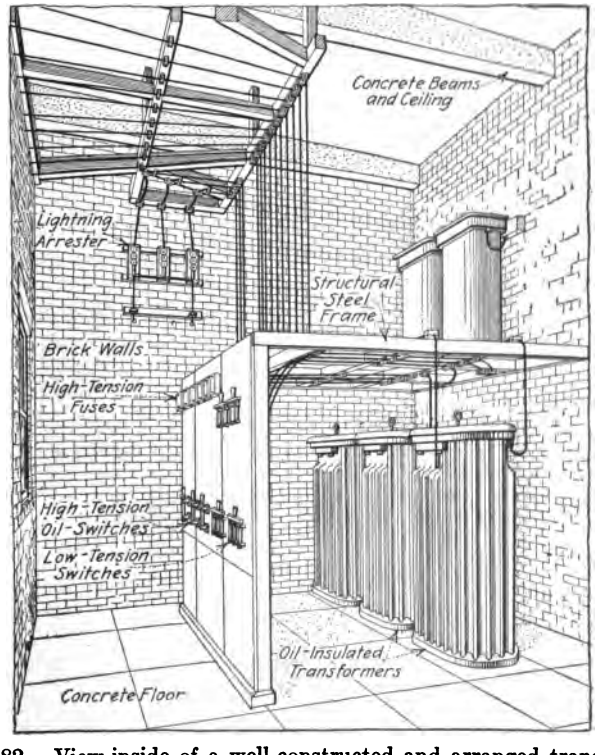


FIG. 382.—View inside of a well-constructed and arranged transformer vault.

45c. ¶*I*. TRANSFORMERS. The transformer case must be permanently and effectually grounded, and the enclosure in which the transformers are placed must be practically air-tight, except that it must be thoroughly ventilated to the outdoor air, if possible through a chimney or flue. There should be at least six inches air space on all sides of the transformer.

Transformer vaults should be ventilated to prevent the escape of smoke to within the building or the spread of a fire in case of the ignition of the transformer windings or the transformer oil. The vault shown in Fig. 381 is ventilated by a window, not visible in the picture, which opens to the outside of the building. That of Fig. 382 is ventilated by a similar method. Note that in both of the installations ample clearance is provided between the transformers and adjacent surfaces.

46. SERIES LAMPS.

46*a*. ¶*I*. SERIES LAMPS. No multiple series or series multiple system of lighting will be approved.

46*b*. ¶*I*. SERIES LAMPS. Must not, under any circumstances, be attached to gas fixtures.

Questions. Class C. (HIGH-POTENTIAL SYSTEMS. 550 TO 3,500 VOLTS)

249. What special precautions must be taken regarding the enclosure of transformers on high-potential systems?

250. In high-potential systems in mill buildings, what is the separation permissible between mains of not less than No. 8 B. & S. gage?

251. How should transformers on high-potential systems be located with reference to the location at which the primary wires enter the building?

252. How are wires in high-potential systems supported when crossing floor timbers or where they may be exposed to injury?

253. How should high-potential wires be protected on side walls?

254. What special requirements affect the installation of multiple-series or series-multiple lighting systems?

255. Should high-potential wires ever be encased?

256. How must high-potential transformer cases be grounded?

EXTRA-HIGH-POTENTIAL SYSTEMS

Over 3,500 Volts

(Rules 47 and 48)

Any circuit attached to any machine or combination of machines which develops a difference of potential, between any two wires, of over 3,500 *volts, shall be considered as an extra-high-potential circuit, and as coming under this class, unless an approved transforming device is used, which cuts the difference of potential down to* 3,500 *volts or less.*

47. PRIMARY WIRES.

47. ¶*I.* PRIMARY WIRES. Must not be brought into or over buildings, except power stations and sub-stations.

48. SECONDARY WIRES.

48. ¶*I.* SECONDARY WIRES. Must be installed under rules for high-potential systems when their immediate primary wires carry a current at a potential of over 3,500 volts, unless the primary wires are installed in accordance with the requirements as given in No. 13 or are entirely underground, within city, town and village limits.

CLASS D

FITTINGS, MATERIALS AND DETAILS OF CONSTRUCTION

All Systems and Voltages

(Rules 49 to 84 inclusive)

These Class D rules are not reproduced herein because they comprise principally specifications for the constructional details of the electric supplies, devices and equipment which are, usually, regularly made by manufacturers and supplied to the user through jobbers and dealers. The Class D rules are given in full in the *National Electrical Code.* The purchaser can identify materials which satisfy the *National Code* (Class D) specifications and which have been approved, by the fact that such materials are designated *N. E. C. S.* (*National Electrical Code Standard*) or may bear the Underwriters' Label.

The Underwriters' Laboratories, Chicago, publishes a "List of Electrical Fittings" which is revised semi-annually and which lists the "approved" electrical devices. The booklet is furnished free on application to the Laboratories or to any local *Underwriters' Inspection Bureau* and should be in the hands of every electrical worker.

The rules (in the Class D section) are but a partial outline of requirements. Devices or materials which fulfill the conditions of these requirements and no more, will not necessarily be acceptable. All fittings and materials should be submitted for examination and test before being introduced for use.

CLASS E

MISCELLANEOUS

(Rules 85 to 89 inclusive)

85. SIGNALING SYSTEMS.

Governing wiring for telephone, telegraph (except wireless telegraph apparatus), district messenger and call-bell circuits, fire and burglar alarms, and all similar systems which are hazardous only because of their liability to become crossed with electric light, heat or power circuits.

The requirements governing the installation of signaling systems (*Rule* 85) are, because of their special application, omitted from this book. They will be found in full in the *National Electrical Code.*

86. WIRELESS TELEGRAPH APPARATUS.

The requirements relating to the installation of wireless telegraph apparatus are, because of their special application, omitted from this book. They will be found in full in the *National Electrical Code.*

87. ELECTRIC GAS LIGHTING.

87*a*. ¶*I*. ELECTRIC GAS LIGHTING. Electric gas lighting, unless it is the *frictional system*, must not be used on the same fixture with the electric light.

88. INSULATION RESISTANCE.

88. ¶*I*. INSULATION RESISTANCE. The wiring in any building must comply with the following requirements:—

The complete installation must have a resistance between conductors and between all conductors and the ground (not including attachments, sockets, receptacles, etc.) not less than that given in the following table:—

Current	Insulation resistance	Current	Insulation resistance
Up to 5 amp.	4,000,000 ohms	Up to 200	100,000 ohms
10	2,000,000	400	50,000
25	800,000	800	25,000
50	400,000	1600	12,500
100	200,000	.....	.....

The test must be made with all cut-outs and safety devices in place. If the lamp sockets, receptacles, electroliers, etc., are also connected, only one-half of the resistances specified in the table will be required.

CLASS F

MARINE WORK

(Rules 90 to 99 inclusive)

Because of their restricted application, these rules are not reproduced herein. They are given in full in the *National Electrical Code.*

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